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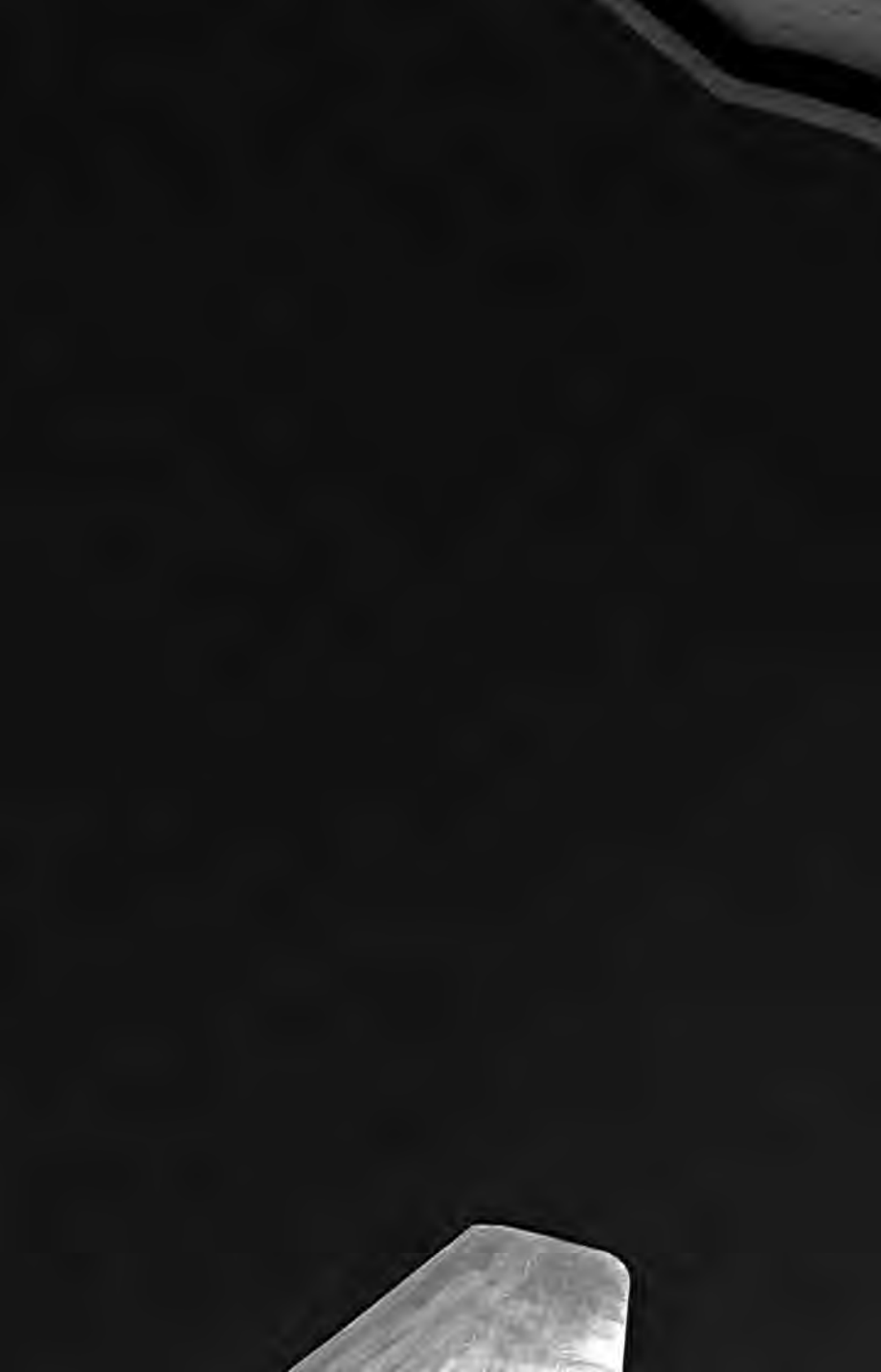
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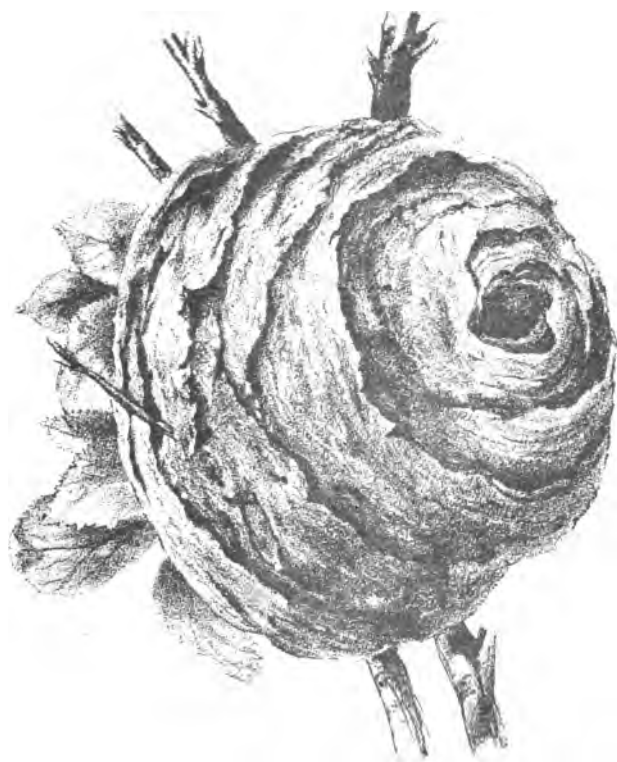
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BRITISH SOCIAL WASPS.







BRITISH SOCIAL WASPS:

AN INTRODUCTION TO THEIR

ANATOMY AND PHYSIOLOGY, AND THEIR LIFE,

AND

GENERAL NATURAL HISTORY,

WITH ILLUSTRATIONS OF THE DIFFERENT SPECIES AND
THEIR NESTS.

BY

EDWARD LATHAM ORMEROD, M.D.,

CHAIRMAN OF THE ROYAL COLLEGE OF PHYSICIANS,
FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS,
PHYSICIAN TO THE SUSSEX COUNTY HOSPITAL.

LONDON:

LONGMANS, GREEN, READER, AND DYER.
1868.



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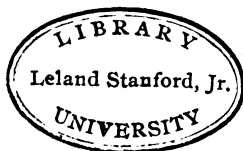
CAIUS COLLEGE, CAMBRIDGE;
FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS;
PHYSICIAN TO THE SUSSEX COUNTY HOSPITAL.

LONDON:

LONGMANS, GREEN, READER, AND DYER.

1868.

" Neat was their house ; each table, chair, and stool,
Stood in its place, or moving moved by rule ;
No lively print or picture graced the room ;
A plain brown paper lent its decent gloom."
CRABBE'S TALES, "*The Frank Courtship*."



HARRISON AND SONS, PRINTERS IN ORDINARY TO HER MAJESTY,
ST. MARTIN'S LANE.

PREFACE.

WASPS have been my holiday companions for many years; and wasps and wasps' nests have occupied much of the time which was forbidden to more serious employments. Beginning with an inquiry into the nature of wasp-paper, one question has led on to another, till the detached observations have insensibly grown into a continuous Natural History.

I feel that I may point with entire satisfaction to the figures of the several species, of the excellency and accuracy of which Mr. Robinson's name is a guarantee to all Entomologists. And of the beautiful drawings of the nests, by my wife's pencil, I am sure that there can be but one opinion, in accordance with my own. The wood-engravings and graphotypes want the perfect finish which can only be given by a practised hand, but I must plead that they convey my meaning more exactly than an artist working at a distance could have expressed.

If the mode in which these observations have been collected has impressed itself too strongly on the book; if it appear only too plainly that while professing to teach others I am but a learner myself; if the space devoted to the different topics seems to have been proportioned less to their actual importance than to the interest of the passing hour; and

if wasps, instead of being the subject, seem sometimes the occasion of the discussion; I can only say that on such terms alone could I have written these pages. Only as an amusement, as each topic came freshly suggested by Nature at a leisure time, could the labour have ever been undertaken, and the idea persistently carried out.

I apprehend, however, no hard criticism to tell me that this book, with all its faults, to which I am keenly alive, should never have been written at all. If I have added anything to our common stock of knowledge, I shall be held excused for having told my story in my own way. And further, if, in so doing, I shall have given as much pleasure to others as I have myself received from such like books, my present contribution to Natural History will have fully answered its purpose.

BRIGHTON,

January, 1868.

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NATURAL HISTORY OF WASPS.

CHAPTER I.

INTRODUCTORY REMARKS.

GENERAL OBSERVATIONS. LITERATURE OF THE SUBJECT. METHOD OF
TAKING AND PRESERVING WASPS AND THEIR NESTS. USE OF WASPS
AND INSECTS GENERALLY.

It is only those who have learned to love wasps as some naturalists love bees who will be at the pains to understand them; who will watch by a nest and learn from the movements of the insects what is going on inside, or will share their study window with a colony of wasps in active work. As far as concerns the profit which is urged as a reasonable pretext for loving bees, I suspect that, if the truth were known, most amateur bee-keepers would agree in the conclusion that the gains accruing from wax or honey are purely imaginary, and that bee-keeping and wasp-keeping are about on a par in that respect. As a scientific pursuit the study of wasps is not surpassed in interest by that of bees; both alike have their peculiar difficulties and facilities, and in both alike nature only reveals her secrets to the close and patient observer.

There is no danger in closely observing wasps and their nests, if we only use a little caution and discretion. It is better not to approach a nest too near on a windy day, or in a hot sun, which always quickens their energies, just

As Heaven's blest beam turns vinegar more sour.*

And we must always look out very carefully for crawling wasps, too weak to fly but not at all too weak to sting, before taking up our post of observation. But wasps at work are generally far too busy to molest any one who does not molest them; and, unlike honey-bees, they do not seem to have any personal antipathies. In some respects they are less open to observation than bees, for they will not work except in houses of their own making, and their first care is to surround the comb by a paper case, impervious to light, or at least to sight. But they are more easily subjected to experiment. For they will work in smaller swarms than bees, and even without a queen; and the affection which binds them to their nest, or to the place where their nest was built, gives us greater facilities of investigating their social economy.

Wasps, to begin at the beginning, have not been found in a fossil state.† The Hymenoptera are well represented among the insects found in amber, but no wasps occur among them. The calcareous marl in the gypsum beds in different places contains remains

* Pope's 'Essay on Man,' Ep. II, v. 148.

† Burmeister, 'Manual of Entomology, translated by Shuckard,' pp. 577—580.

of Hymenoptera, but no Vespæ, only some Polistes have been found there. Though they have left no pre-historic remains, wasps found a place in literature early. It does not appear, however, that they were at any time regarded with different feelings to those which are generally entertained towards them in the nineteenth century. They have always been looked upon as the petty impersonation of every thing actively annoying and disagreeable. Homer* draws them, with one of his touches of nature, as beautiful and as restless then as now, the same in all their habits, unchanged during more than 3,000 years. He makes Asius, rushing out from Troy, and chafing with vexation because the enemy will not come out to meet him when he wants, compare the Greeks to wasps guarding their nests. And though the hero does give the dignified title of huntsmen to the takers of wasps' nests, we must understand this compliment as half intended for himself under the circumstances. The author of the mock heroic Battle of the Frogs and Mice,† does not give hornets, as Parnell has rendered it, but gnats, *κώνωπες*, the honour of sounding the trumpet for battle. Aristophanes‡ lashes under the name and guise of wasps the Dicasts of his day, who fostered litigation, and lived at the public expense on the quarrels which they made. He terms wasps the most irascible and peevish of all creatures; and their want of a sting cannot purchase a word of favour for the drones. For these are guilty of the yet graver offence of living in idleness on the ill-gotten gains of the rest

* 'Iliad,' XII, 167, μέσον αἰέλοι.

† Book III, v. 5.

‡ Wasps, v. 1104.

of the horde.* The man who misjudged Socrates as a Sophist could scarcely deign to understand a wasp. Again,† when Poverty enumerates the physical advantages which her votaries have over those of wealth, and mentions wasp-like (or as we might render it straight, or strait, with a double meaning) among their other happy qualifications, this attribute at once turns the tables against her. Chremylus winces at this, and suggests that hunger is the cause of the undesirable result. But, in short, no one has a civil word for them, and the choice of epithets which are offered in the *Gradus* to those who wish to write verses about them are so vituperative that one feels gratified, under the circumstances, that wasps have never become a favourite theme with either poets or poetasters.

Yet there was no want of knowledge on the subject, and in the first systematic Natural History which has come down to our times, that which Aristotle‡ put forth, the observations on wasps compare favourably with those on many other animals quite as familiarly known. He was aware that the colony originated from a single wasp which survived the winter, and that the nest was, in the first instance, the sole work of this insect. He knew that the cells were made larger, as the season advanced, for the mother-wasps, which were then produced; and that

* So Virgil, 'Georgics,' IV, 244, of the drone-bee:—

"Immunisque sedens aliena ad pabula fucus."

† 'Plutus,' v. 561.

‡ 'History of Animals,' published about 330 B.C. I have referred to Cresswell's translation, 1862, both as more generally accessible than the original, and as supplying, in the valuable notes and index, a help which every student will appreciate.

the labour of building was at this time delegated to the workers. The chief difficulty in following his account seems to arise from his not having sufficiently distinguished the species. His meaning is generally clear enough with regard to the social economy of the *σφήκες*, but when we get to the *ἀνθρώποι* * all is confusion, and it is not clear whether it is always the same insect which is thus designated.

Wasps and their ways have a place, though not of honour, in various works. The fabulous legend of St. Veronica† makes her cure Vespasian of a wasp's nest in his nose by the sight of her miraculous cloth: this inconsistent silly story having been evidently concocted in forgetfulness that in Vespasian's time, whose name the story was made to fit, *vespa* was not the familiar word for a wasp. Coming nearer to our own times and country, we find Olaus Magnus,‡ of Sweden, in the 16th century, devoting a chapter or more of his 'Natural History of the Northern Nations' to them. He slides gradually into their description from that of stag-beetles, and so on, by a transition which seems to him equally natural, into that of snakes.

The general classification is strange enough; but the division into large and small wasps, and the few touches of description are true to nature. Mallow

* Op. cit. Book V, Chap. 20. Book IX, Chaps. 27, 28.

† Mrs. Jameson, 'History of our Lord, as exemplified in Works of Art,' Vol. I, p. 41, referring to an illustrated MS. in the Ambrosian Library at Milan.

‡ 'Historia de Gentibus Septentrionalibus,' etc. Folio. Basileæ, 1567. Lib. XXII, capp. 3, 4.

leaves were the approved remedy for wasp-stings in his time, and he tells us that hornets, the large orange-yellow wasps, were called *Boolgetingh* in the Gothic language.

Wasps and hornets have never wanted names in our islands. Lhuyd* gives *kakkynen* for the Welsh name, *chuilkiores* and *guihien* for the Cornish, and *eirkveach* for the Irish, while the Armorican *guezpeden* and *guezpel* show that the late Latin *vespa*, which has since been so widely adopted, was already creeping into use. The epithets† familiarly applied to wasps and hornets in the Welsh language, such as yellow-tailed, carpenter, singer, might seem to denote that the Welsh took a great interest in the insects whose characteristics they thus stereotyped. But Welsh scholars assure me that they are not favourite subjects of allusion in the Triads, and that the form of the language, not affection, dictated the mode of expression.

Ordinary observation, as far as this went, was correct enough; but when any thing more is attempted, where any description of habits occurs, the want of a proper distinction of species becomes apparent, resulting in the strangest contradictions. The same confusion which makes many of Aristotle's remarks unintelligible prevails, and even to a greater degree, with the accumulation of additional observations, in all the subsequent histories of wasps, till quite a recent period: even Réaumur's‡ great work

* Lhuyd, 'Archæologia Britannica.' Folio 1707.

† Owen's 'Welsh and English Dictionary.' 2 vols. 4to. London, 1803.

‡ 'Mémoires pour servir à l'Histoire des Insectes.' Tome VI. I

does not wholly escape its influence. Among the precious remains of Hunter's manuscripts,* which were saved from the flames, are two papers on the 'Economy of Hornets and Wasps,' to which, as well as to his 'Observations on Bees,' there will be frequent occasion to refer. It is remarkable how this great man's habits of accurate observation, and of not inferring beyond legitimate grounds, have produced Essays, which, examined by the light of all that has been learned since his time, still appear—to my prejudiced mind perhaps—almost faultless.

However, ample justice has been done to wasps at last. The clue to all the seeming irregularities in the proceedings of an insect usually working by fixed unchanging rules was suspected to exist in a want of proper discrimination of the several species. And this source of error has been finally removed by the labours of Mr. F. Smith,† who has condensed into the space of a few pages the description of the specific characters of the British Social Wasps, and after so many years has realized Latreille's‡ wish for another Kirby to clear up the Natural History of the Wasp Family.

The literature of wasps is not large. Hagen,§ regret much that I have not this work now accessible, to correct and enlarge my references to its charming pages.

* Hunter. 'Posthumous Works by Owen.' Vol. I. On the Economy of Hornets and Wasps.

† Smith. 'Catalogue of British Fossorial Hymenoptera, Formicidæ, and Vespidæ, in the Collection of the British Museum.' London, 1858, pp. 211—222.

‡ Westwood. 'Introduction to the Modern Classification of Insecta.' Vol. II, p. 248.

§ Hagen. 'Bibliotheca Entomologica.' II Band. 8vo. Leipzig, 1862—63.

in his wonderfully learned Index, for which entomologists can scarcely thank him enough, gives a list of scarcely more than fifty writers on this branch of Entomology, the greater part of whose works on this subject consist of papers contained in journals or transactions of societies. To several of these authors it will be sufficient to refer from time to time; but there are others whose works have been so constantly in my hands that I could not adequately express my obligations to them by such occasional citations. Of these, I subjoin a list:—

- Burmeister. 'Manual of Entomology,' translated by Shuckard. 8vo. London. 1836.
- De Saussure 'Etudes sur la Famille des Vespides.' 3 tomes. 8vo. Genève et Paris. 1852-58.
- Hunter. 'Observations on Bees.' Collected Works. Vol. IV. 8vo. London. 1837.
- Kirby and Spence. 'Introduction to Entomology.' 7th edition. Small 8vo. London. 1856.
- Newport. 'Insecta, Cyclopædia of Anatomy and Physiology.' Vol. II. Roy. 8vo. London. 1836-39.
- Smith. 'Catalogue of British Fossorial Hymenoptera, Formicidæ, and Vespidæ in the British Museum.' 12mo. London. 1858.
- Westwood. 'Introduction to the Modern Classification of Insects.' 2 vols. 8vo. London. 1839-40.
- Westwood. 'Entomologists' Text-Book.' 12mo. London. 1838.
- Wood. 'Homes without Hands.' 8vo. London. 1866.

Wasps are not to be studied from a distance only, like the stars. It may be necessary very frequently to come to closer quarters. And though much may be done by tact and discretion, there is no way of preventing them getting angry and attacking the offender, when such a very extreme measure as taking their nest is resorted to. Wasps, as we shall see, will bear many things, but they would not be wasps to stand this. So, as it may be necessary to take their nests occasionally, it is as well to consider how it may best be done. If we do not want our labour to be wasted, we should survey the nest carefully, and ascertain the direction of all the roots and branches which support or traverse the fabric before we set to work. We must take care that there are all the proper tools handy. And we should bear in mind that without great caution we may carry away very unpleasant, if not serious, reminiscences of a holiday, in a swelled arm or face, and be well laughed at besides.

There are various ways of taking wasps' nests, all more or less exciting, dirty, and dangerous. All these elements of enjoyment must have met in the highest perfection in the mode of procedure which Euripides* leads us to infer was in vogue with Young Athens in his days. The Chorus, under the guidance of Ulysses, propose to poke out the Cyclops' single eye with a firebrand of appropriate dimensions, in the same way as they have been used to operate on wasps' nests. Now, although in the prospect of this somewhat ticklish operation of belling the cat, of which they have very disagreeable anticipations, the

* 'Cyclops,' v. 475.

classical Chorus speak confidently of what they have done in the smaller way, and exhort each other to go in and win accordingly, yet we cannot doubt that the modern invention of gunpowder has given the attacking party great advantages. And the classical torch could not have been nearly so safe or effectual as the squib which Young England brings into the field.

Where the object is simply to destroy the swarm, as completely as possible, and with the least trouble, this is best effected by pouring a little tar into the entrance in such a way that each wasp as she comes in or goes out shall get a smear on her legs and wings. Nothing more is seen of the swarm after this operation has been well performed; and in a few days the nest may be dug out, with the certainty of finding not a single living wasp in it. This plan, however, is almost exclusively applicable to ground-nests, where there is a surface to be tarred over which the wasps must walk. For the tree-nests, after all, the ancient firebrand or its modern substitutes are the best instruments of destruction when only green leaves and no hay-ricks are near, and the nest is not wanted for a specimen. But when we wish to preserve the nest we must proceed in another way, and the best, indeed the only way, is to cut it down or dig it out, taking care neither to injure the delicate structure, nor let ourselves be injured during what may be a very lengthened operation. Mr Wood* mentions a hornets' nest which took six hours' continuous labour to cut out of a tree.

For this purpose a pair of strong gloves are wanted, with short sleeves sewn to the tops to tie round the

* 'Homes without Hands,' p. 439.

arms below the elbows. The trousers should be tied over the ankles to prevent crawling wasps gaining access that way, and it is better that these should not have been worn thin in parts, nor be of the lightest summer material. A wide-brimmed hat; a strong net veil, sewn together down the back and the lower edge tucked carefully under the coat collar; and a handkerchief packed under the chin, make the armour complete. The veil should not be so loose or light as to be readily blown against the nose or ears, for such points of contact will be immediately pounced upon by the angry swarm. I have found these precautions quite sufficient for the safe capture of any wasps' nest. I never had an opportunity of taking a hornets' nest, but I should be inclined in such case to proportion the thickness of my clothing to the length of their stings, and would put on a good substantial suit of fustian for the occasion.

As soon as the nest has been secured (which is rather hot work on a summer's day, in a close fitting suit), carry it some twenty yards or more from the place whence it has been taken. For then the wasps, as they fly out, will return to their homestead and leave you unmolested. If the swarm is wanted with the nest, for experiment, they should be transferred, with as little delay and the loss of as few wasps as possible, to a box which has been so prepared as to allow of its being easily got out again. In the absence of any such preparation it should be simply turned upside down, as it will travel safest in this position. But the best way is to transfix the nest on the spot, through the dry hard upper part, with one or more wires, according to its weight. If the ends of these

wires are attached to strings passing through notches in the lid, the nest may be slung at once in the box and may be removed, when required, with perfect safety both to its own structure and the fingers of the operator.

If we wish to preserve the nest as a specimen, the best way is to cut round the top with a sharp knife or large pair of scissors, and extract the comb in a mass through the aperture. The old dry deserted comb at the top of the nest is to be retained in its place, and one or two of the lower stages should be preserved. The rest may be thrown away. When the specimen has been brought home, carefully pick out the grubs from the lowest stage of comb, and replace this in its proper position so as to show at the orifice of the nest; fill up the centre with cotton wool; replace the top, and fasten the cut edges neatly together. Then sprinkle the specimen well with some preservative solution to destroy earwigs or wood-lice, and, after a few days' quarantine and a cautious baking, it will be fit for the cabinet. It will need, henceforth, only protection from dust and damp, and an occasional sprinkling with a solution of phenic acid, mineral naphtha, or some such fluid. Hung from a string in its natural position, or turned upside down and mounted on a card with a comb by its side, it will last for years. Nests of only moderate size make the best cabinet specimens.

So much for the preservation of the nests, now for the wasps themselves. And, by the way, as it is scarcely likely that these investigations can be carried on without an occasional sting, it may not be out of place here to speak of the treatment of this

incidental trouble. Gerarde* mentions only rue and mint and mallow as the best applications to the part stung, and attributes to mallow leaves and oil preventive as well as curative virtues. Sennertus,† a very high medical authority in his day, mentions several remedies, either simply soothing poultices, or applications of aromatic herbs. He gives to a mixture of coriander and sugar the highest place. But, while these are being sought for, he advises the wound to be sucked, or a poultice made of the offending insects—a hair of the dog that bit you—to be applied, to draw out the poison.‡ Fabricius Hildanus, whose surgical writings are quoted at the present day, harps on the same string, and sums up a narrative of several cases of serious injury from a wasp's sting with a grave argument in favour of oil of wasps as a remedy for the effects of their venom.§ These all have had their turn, and are gone out of fashion. Even tobacco and a watch-key have had their date and been forgotten, to be suggested again as new remedies. The popular remedy now-a-days, which has had a long run of public favour, is scarcely less absurd than a wasp-poultice. This is a mixture of indigo and Prussian-blue, known to washerwomen

* 'Herball, by Johnson.' Folio, 1633. Table of Vertues. See also Paulus Aegineta, 'Commentary by Adams,' Book V, § 5. Syd. Soc. Vol. II, p. 169.

† 'Sennerti Opera.' Folio, 1650. Tom. III, p. 658.

‡ So Celsus. Scorpio ipse sibi pulcherrimum medicamentum est.—'De Medicinâ,' Lib. V, cap. 27. § 5. 8vo. Lugd. Bat. 1746.

§ 'Fabricii Hildani Opera Omnia.' Folio, Francofurti, 1682. Cent. Observ. VI, § 88. Ploucquet, 'Literatura Medica digesta,' under Iorus, gives a long list of references, which the curious on this subject might consult with amusement, if not with advantage. 5 tom. 4to. Tubingæ, 1808—14.

as stone-blue, laid on thick with vinegar or water. Perhaps there may be some comfort from the local application in the same way as dredging with flour gives unquestionable comfort in erysipelas. But I must be allowed to express a doubt whether there is anything more than this, and whether red-ochre,* or whiting would not do nearly as well as indigo,† which, once famous in medicine, has, in its turn now dropped out of the Pharmacopœia. Nearly as well: but there is a great charm in the colour; something must be allowed for that; and such an opportunity of making a mess, under authority too, is a great event in a little child's life. Hunter,‡ who had large personal experience of stings of bees and wasps, dismisses the subject in one line:—"I have heard of cures, but I never experienced one." Ammonia or soda will sometimes relieve the pain, and chloroform more certainly and speedily, should it be at hand. Ipecacuanha is a favourite Indian remedy. But the best way is gently to withdraw the sting, and suck the wound if we can get at it, and then to leave it alone. Some persons swell very much after a sting, and for these rest and a good dose of purgative medicine are the best treatment. But, above all, leave the wound alone. And so far as whiting or indigo conduce to this end by excluding the air from the swelled tender skin, by finding the poor little child something to do, or keeping the older patients

* Mr. Lord, 'At Home in the Wilderness,' London, 1867, p. 281, says that the North American Indians of Columbia use vermilion for a similar purpose, and with equal success, medical and artistical.

† Beckmann, 'History of Inventions,' ad rem.

‡ Hunter's 'Posthumous Works by Owen,' Vol. II, p. 457.

from teasing and squeezing the part, they do good; and they may hold their place as potent remedies till the wheel of fashion brings up something else instead of them.

A little practice will make any one far more proficient in *setting* wasps than any amount of written directions. But it can do no harm, and may save much time at first to be put in the right way. Newly hatched wasps are very likely to turn black after a little while; so that if we have only such specimens it is better to keep them alive for some days before doing anything with them. We may kill them readily by dropping them into a corked bottle with a little benzol, better known as benzine collas, or chloroform, at the bottom. The first of these is the best: it is less volatile, so that the poisoning bottle will not require to be replenished so often; and its effects are more permanent. After a few minutes the wasps may be removed from the bottle and spread out to dry; and if then no signs of life appear we may clean and set them at once.

For this purpose, take the wasp between the left thumb and forefinger, and squeeze the abdomen gently, removing the viscera, as they protrude, with a pair of forceps and a bit of rag. Then wipe out the inside of the abdomen with a little cotton wool, and when it is quite dry insert a small tuft of this to prevent the abdomen from shrinking. With care all this may be done without cutting, or even without displacing any of the rings. Next draw the legs out gently, and particularly attend to the tibio-tarsal joints, straightening them, not by pulling, but by pressing, so that they may readily take any required

position without fear of breaking. Now pass a fine but strong pin through the thorax, and set the insect on a cork-board. The legs will keep their position in drying, but the antennæ will need support, and perhaps the head also. The chief trouble is with the wings, on the neat adjustment of which so much of the beauty of the specimen depends. The best way to manage these is to fix a long pin obliquely into the cork-board on either side, parallel to the body of the insect, making an inclined plane on which the wings may rest when they are expanded. Now open the fore-wing very carefully, with one blade of the forceps, and draw it over the hind-wing, up this plane. After one or two trials the row of little hooks which are found along the front of the hind-wing of the wasp will hook as they naturally do in flight, and the wings thus fastened will look much better and retain their position more securely than when they are adjusted by pins. They are to be held in this position by another long lighter pin lying over the stronger one and nipping the wings between them. This must be repeated on the other side, and the limbs must be re-arranged where they have been disturbed; and then the specimen only needs drying to be complete. Sometimes, by merely blowing them, the wings may be properly expanded, and if, luckily, the hooks can be made to catch at the same time a great deal of trouble will be saved thereby. When the specimen is very small, as will be the case if we extend our researches beyond the *Vespæ*, pins and forceps will be of no use in spreading the wings, but will only tear them. The best way then is to float out each wing, with a drop of water, on the

end of a slip of card neatly brought up to the side of the insect as it stands on the setting-board. As the water evaporates, the wing will retain its form on the card, and this will drop off, when quite dry, by its own weight. Folded wings which have resisted all other remedies often yield to this.

The specimens, especially those of the larger insects, require a good deal of subsequent care. They are liable to turn greasy and soil the paper on which they are mounted; they are the prey of little mites as well as of larger insects; and if they are kept in the sun they are liable to fade. But wasps are plentiful, and we need not grudge a little trouble in setting a few specimens more or less, when it adds so much to the beauty of the cabinet to have each nest ornamented by its own wasps.

The knowledge of insects which is limited to the external appearances of dried specimens, is literally only superficial. We must take their outer case to pieces, and look inside it, and examine its disarticulated fragments, if we wish to study their natural history to any useful purpose. Insect anatomy is capital practice,* but it is a study of much difficulty, requiring great patience; and, as we may calculate on spoiling many specimens, it is of importance to secure a supply of the largest wasps, and in the freshest and healthiest condition possible. The perfect females which are found in the spring seem to answer best. Having contracted with little boys to furnish these alive and unhurt in any required quan-

* See Cuvier's opinion on this point, as told by Audouin, in 'Kirby and Spence's Introduction to Entomology,' 7th edition, pp. 12, 13 note.

tity, we should keep them in a broad-necked bottle till leisure and sunshine to examine them come together. A few strong straws, or light twigs, should be crumpled into the bottle for the wasps to cling to. They should have a little biscuit or sugar, and plenty of water; and be kept in the dark and cool till wanted.

The tools which we want are very few: no more than what each microscopist already has. With a sharp-pointed pair of scissors, a pair of dissecting forceps, two or three mounted needles, a leaded cork and a soap-dish full of water, our repertory is complete. Though the possessor of a binocular dissecting microscope may perhaps wonder how any one could not call this most useful instrument indispensable.

Fully believing that pain, as we feel it, is not an attribute of insects, I must yet own to a great horror of any signs of vitality whatever displaying themselves in a wasp under examination. So, before commencing the dissection, I like to feel quite satisfied that the insect is dead. All these dissections must be made under water, as the tissues are too soft to retain their figure without some such fluid support. It is easier to make the necessary openings in the integuments before fastening the specimen to the cork. Having done this, and pinned the insect out in such a way as to interfere as little with the dissection as possible, we have only to wait till the air-bubbles clear away to set to work. We may want the scissors occasionally, but the most useful instruments are the needles, always working under water.

Many structures of wasps have a peculiar conformation, and, of course, in wasps only can these be thoroughly investigated. Conversely, we should look in vain in wasps for much that we find in other insects. If our idea, however, of insect structure in general is to be drawn from one insect, a wasp will serve as well as any other example.

It might be said, fancifully perhaps, that in many respects an insect is like a vertebrate animal reversed. The student of human anatomy has his attention directed to each prominence on the outside of the bones as indicative of the strength of the muscle attached to it, and of the mechanical functions of the part. It is not outside, but inside the bones of insects that these indications are to be found, the same horny plates serving the purpose both of skin and bone. So again, while in Vertebrata the blood is brought from the tissues to the air in the lungs that it may be oxygenated, in insects, as we shall see, the air is brought to the tissues and to the blood lying loose in a series of membranous sinuses. And such illustrations might be multiplied.

Again, fancifully, it might be said, taking an illustration from the vegetable kingdom, that insects are endogenous, having their growth limited by their external investment, and their structure physiologically prescribing the term of their existence. Subject to such restrictions, and within these limits, nothing more beautiful or perfect in adaptation can be conceived than these tiny organisms. They illustrate perhaps the highest point to which organization can be carried on the endogenous plan. Larger size, capacity of growth, and longer duration of life, are

only attainable by a different arrangement of more varied materials.

The life of an insect has often served to point a moral as to our own present and future state, the grovelling worm—the pupa in its death-like sleep—and the perfect insect rising in all its new beauty from the grave, have been fancifully said to typify the successive stages through which our own being is destined to pass. But the illustration is neither as accurate nor as beautiful as that which St. Paul* adopts. For, though insects may be said to be perfect, as insects, each with their one idea, and for their one purpose, yet the imago should be called rather a changed than a perfected being. It has new faculties indeed, and a wider range, but it has often a less intimate relation with the world at large; and it often plays a less useful part in its winged form than it did as a grovelling worm. And in many—most insects—the shorter existence of the imago, compared with that of the larva, sadly mars the point of this illustration as a type of eternity.

The real analogies of insect life are to be read in quite a different way. Professor Owen† has put this very happily:—"If the different stages in the development of man were not hidden in the dark recesses of the womb, but were manifested, as in insects, by premature birth and the enjoyment of active life, with a limitation of the developmental force to mere growth; if the progress of development was thus interrupted and completed at brief and remote periods, with great rapidity, and during

* 1 Cor. xv, 37.

† 'Lectures on the Invertebrate Animals,' p. 248.

a partial suspension of active life; his metamorphoses would be scarcely less striking and extreme, as they are not less real, than those of the butterfly."

There are few insects which as obviously minister to our comfort and well-being as the honey-bees of which we take so much care, and which we regard affectionately as the type of useful industry. But, from the large quantity of rotten wood which they destroy, and of flies and caterpillars which they consume, we may fairly regard wasps as no less our real benefactors; and we may look with more forbearance on the toll which they exact from our gardens in the autumn in return. Among most insects, and perhaps cockchafers and blow-flies supply the most familiar instances, it is the larvæ themselves which prey directly upon the animal and vegetable matters intended for their food. But among wasps, and some other Hymenoptera, it is the perfect insect which collects the scattered materials, and thus occupies a much wider field than could come within the range of the larva. These materials are rotten wood and garbage of all kinds, and, besides these, all the insects that they can master. It will be admitted that they devote themselves to this part of their duties with great assiduity, making prize of all flies, spiders, and caterpillars; bees, and even other wasps, not being excepted. It would be very difficult to prove absolutely that wasps have a sensible influence in diminishing the number of flies and of other insects. But it is the conviction of some of those who have paid attention to the subject that this is really the case. Among others, Mr. A. Bryson, F.R.S.E., of Edinburgh, the friend and

biographer of the late Sir Thomas Brisbane, has assured me that the practical result of destroying all the wasps on Sir T. Brisbane's estate was, that in two years' time the place was infested, like Egypt, with a plague of flies. At every wasp's nest you might have gathered a handful of the wings of insects;* and the flies throve apace when the wasps were killed.

We do not readily appreciate the indirect benefits which we derive from the labours of wasps, just as we are not perhaps properly grateful to beasts of prey for their equally unsolicited assistance. Cats, and weasels, and foxes, though they are not good to eat, are often much more acceptable neighbours to the farmer than rabbits. And the colonist, brought into contact with nature in her wilder forms, knows well how the larger beasts of prey serve him by keeping in check the animals of which he more immediately and consciously makes use, but which very animals, without these restrictions, might prove more injurious to him than beasts of prey ever do.

As Man takes possession of the soil, the beasts of prey retire before him, and we, in a certain sense, undertake their duties. The duties of insects, however, are not so obvious, nor so easily within our power to fulfil. We scarcely know what we owe to them so long as they confine themselves to the fertilization of flowers, to destroying decaying organic matter, or to keeping each other's numbers within due bounds. It is when they exceed these limits, when they hurt

* I acknowledge with great pleasure Mr. Bryson's kind communication in further explanation of his letter in 'The Times,' On behalf of wood-pigeons and sparrows, December 17, or later, 1864.

us or damage our property, that we first become aware of their existence, and that we feel their importance. And then we call in the aid of the birds to destroy for us enemies against which we are ourselves almost powerless; or of Science to teach us to destroy the nidus in which the pest is propagated.

The most enthusiastic advocate of the principle of non-interference, of the rule of live and let live, would hardly demur to the occasional intervention of Man, for whose use all these creatures were designed, as a natural part of the general balance of power among animals. It is only a small part, however, as concerns insects. And as the dictates of philosophers are not always right, and the wants and whims of man and woman-kind, which more often determine which of the smaller animals shall be spared, and which doomed to destruction, are still more fallible, it is a comfort to think that man's power in this respect is so limited, and that his decision is not final. Otherwise, the subjects of this work would long since have shared the fate of the dodo and the moa.

CHAPTER II.

CLASSIFICATION AND DISTINCTION OF THE SPECIES.

HYMENOPTEROUS INSECTS GENERALLY. WASPS—SOLITARY, SOCIAL.
BRITISH SPECIES, THEIR DISTINCTIVE CHARACTERS AND HABITS.

WASPS constitute a subdivision of the large Order of Hymenopterous Insects. This order is characterized by the possession of two pair of clear membranous wings, from which it takes its name, and of a peculiar instrument placed at the end of the abdomen in the female sex. This instrument has been adopted as a means of classification, the Order being subdivided into tribes according to the different structure and functions of their appendage. In the Sirex and Saw-flies it is a piercer or saw. In the Gall-flies and Ichneumons it is an apparatus of pointed bristles. In the Ruby-wasps it is a telescopic tube. And in the four remaining tribes, which are hence called the Aculeate Hymenoptera, namely, Ants, Bees, Wasps, and Sand-wasps, it is a sting.

There is no difficulty in distinguishing wasps from the tribes first mentioned, nor, in most cases from ants. And the British species of wasps, at least, with which we are here alone concerned, can scarcely be confused with any of our bees or sand-wasps. It will be needless, therefore, to enter into a detailed

description of all their differential characters; it will be sufficient to indicate them generally, as displayed in the typical species.

Bees then have a long strap-shaped tongue or proboscis; the hind legs are flattened out and hairy, and the basal joint of the feet, that is to say the one nearest the body, is very much larger than any of the others. The fore-wings are marked in a way peculiar to bees, and are not folded in repose. The tribe of Sand-wasps in the same way have peculiar markings on their fore-wings, and do not fold them in repose. Their tibiæ, that is to say the long bones next above the tarsi, are armed all down with strong spines, and are very much stouter in proportion than the corresponding limbs of the wasp.

The Wasp tribe are provided with stings: their tarsal joints, unlike those of bees, are of a regularly proportional size, and their tibiæ, unlike those of sand-wasps, are long and slight, and armed with spines only at the distal extremity. The fore-wings are marked with undeviating regularity by certain nervures differing in the several families, and when in repose are folded longitudinally. By this single character of the longitudinal folding of the wings the Eumenidæ or solitary wasps, and the Vespidæ or social wasps, are somewhat arbitrarily, as it might seem, and artificially, united into one family, hence called *Diplopteryga*. By this rule the Eumenidæ are separated from the Fossores or sand-wasps—which do not fold their wings—to which they seem much more naturally allied. The distinction, however, appears much less arbitrary in the Exotic than in the British Fauna. In our islands, indeed, the transition from the

social to the solitary group is very abrupt. And the two species which represent the solitary group seem forced into an unnatural position, when united with the typical genus *Vespa* of the social group, to the neglect of their more obvious relationships. But in the Exotic Fauna, where all the connecting links are supplied, this objection disappears. The Vespidae shade into the Eumenidae by as gradual steps as these do into the Fossores, clinging by their anatomy to the former, by their habits to the latter division. And, since some artificial distinction must be adopted, perhaps that which the folding of the front wings supplies is as little arbitrary as any other.

The EUMENIDÆ, or solitary group, are very widely distributed over the surface of the globe. Perhaps they are less variously represented in Great Britain than in most other places; for we have only one very local species, *Eumenes coarctata*, and twelve varieties of *Odynerus*, or of kindred species not readily distinguishable from it. The natural history of the solitary wasps does not come within the proper scope of these remarks, so I will not enter upon it at length, but only give a short sketch, as far as they have come casually under my observation, of the appearance and habits of the *Odyneri*, which, to most of us, typify the British Eumenidae.

They are small, dark-looking wasps, having the abdomen banded with black and yellow in the strongest contrast, the black generally predominating. The abdomen is spindle-shaped, tapering off at each end. The head is broad and flattened, the compound eyes large and projecting. The mandibles are long

and pointed, crossing each other when at rest, and armed, as the microscope shews us, with five teeth. The tongue is longer and more deeply cleft than in the *Vespæ*. The arrangement of the nervures of the wings is very like what there will be occasion to trace further on as displayed in the social group. The technical character by which social and solitary wasps are most readily distinguished is found in the tarsal hooks, which are simple in the social and denticulated in the solitary group, and, by the aid of the microscope determining this point, the *Odyneri* may at once be referred to their proper place as solitary wasps.

In a social and physiological point of view the differences between these groups are very obvious. Still taking the *Odyneri* as the most familiar type of solitary wasps, we find among them only perfect females and males, the latter much smaller than their partners. There are no imperfect females. Both sexes appear at the same time, early in the summer, and shortly set about the work of their lives. The mother-wasp makes cells of sand, or any other material, agglutinated with mucus. She deposits an egg in each cell, and with it a store of small caterpillars as food for the larva against the time when it shall be hatched. These caterpillars she stings, not so as to kill them outright, for in that case they would dry up or putrefy, but just enough to paralyze them. As some exotic species seal up small insects and spiders in this way it is necessary to keep them quiet, otherwise the tables might be turned on the larva, and it might be eaten up itself instead.

When the mother-wasp has built and provisioned

and sealed one cell she goes on to prepare another in the same way. The *Odyneri* build several of these together, but *Eumenes coarctata** makes each cell separate, fixing them on the stems of the heath, each little round bead with its egg, its caterpillars, and perhaps its parasite. In due course of time the egg hatches into a larva, which eats up the food so carefully provided for it, and then, having lined the walls of its chamber with a smooth silk web, changes into a pupa, and so sleeps through the winter.

The maternal duties of the mother-wasp seem to cease with the closure of each cell; after she has put in the food and closed the door she has no further care for the future brood. It depends on the capacity of the hole she has selected whether she shall have more than one nest. Whether she shall lay her eggs in one or in many places is indifferent to her; for there is no tie to attach her to the place, there is nothing more that she can do for her progeny. Her work can scarcely be called a nest, as that word is applied to the wonderful structures of the social wasps. It is merely a collection of cells of all shapes, packed without any order into the most out of the way places. I have one from inside the lock of a kitchen door. Here, in a thoroughfare from the kitchen to the scullery, with all the passing backwards and forwards, and the banging, and the cooking, the mother-wasp had laid up her brood, and brought in all their future sustenance through the keyhole. And here the pupæ had lain safe for months, till, on the report of what had been noticed in the summer, the lock was unscrewed to display what no lock-

* Wood. 'Homes without Hands,' p. 352, and fig.

smith would ever have dreamed of finding in such a place. A neighbour, if not a relative, of this wasp tried perseveringly, but without success, to establish herself in the housekeeper's work-box, and another temporarily took possession of the keyhole of the kitchen clock-case, which, but for the weekly necessity of winding up the clock she might have permanently occupied. Undisturbed by accidents, another colony of these little creatures slept unheeded in the drawer of an old-fashioned looking-glass through the winter; and one fine summer morning a dozen or more wasps greeted the astonished eyes of the housemaid.

The *Odyneri* are not very conspicuous insects, and, except in quest of nesting places, do not generally obtrude themselves on public notice. If we look out for them we may find them and their nests everywhere, the wasps about every flower, the nests in many a neglected window-frame. But unless we are in quest of them we may readily overlook them, and at least they very rarely inform us of their presence by their sting. Probably with most persons they might pass for coloured flies, and so escape the summary execution which awaits all insects called wasps when caught. I would not willingly correct a mistake which preserves the lives of these little useful creatures, whose whole existence is spent in our service. It is literally so: the quantity of caterpillars they destroy is quite incalculable. Rarely, if ever, do they interfere with us, unless an ill-fitting mortice, or an old drawer, tempts them to claim some hospitality in return for the good service which they are always doing us. I commend them to the pro-

tection of every one who has a garden of his own, or can share in the enjoyment of one.

The VESPIDÆ, or social wasps, are represented in our islands by their typical genus the Vespæ only. Of this we have seven species, including the hornet. The Polistes, which makes its nest without any outer covering, though so very widely distributed, is quite a stranger to us. We have no representative of the pasteboard-wasps of British Guiana, of the mud-wasps of India, nor of any of those which hang their flimsy structures by threads to twigs or leaves. On the other hand, the Vespæ are unknown in Australia, though well represented in the Indian Archipelago.

The Vespæ, and particularly our British species, constitute a singularly natural group, separated from allied species by well defined characters. They are large insects; some of them very large. *V. magnifica*,* of Nepaul, measures from tip to tip of her wings 3·6 inches, and is 2 inches in length. *V. cincta*, more widely distributed through the East Indies, only attains the modest dimensions of 2·5 inches across, by 1·25 long. Our own *V. Crabro*, with as large a body, has a somewhat shorter span of wings, only 2·15 inches. With these and a few other exceptions,† generally there is no very notable difference of size between the Vespæ or wasps, as we shall henceforth call them, of temperate and of tropical regions. Wasps are delicate, and very susceptible of injury

* De Saussure. 'Monographie des Guêpes Sociales,' p. 155. Planche XIII, fig. 3.

† Smith. 'Catalogue of Hymenopterous Insects,' Part V. *Vespidæ*, 1857, pp. 119, 120, and plate of *V. mandarinia*. Tab. V. fig. 4.

from cold and wet, though some species are found in high northern latitudes*. But, wherever they occur, the family resemblance is well preserved, and the insects are clearly and easily recognizable as wasps by their form and colour and habit. Varying however in the mode in which they build their nests, and in the materials which they employ, according to the various necessities or opportunities of the climate or locality.

It is however only with a small portion of this group that we have now to do. My own observations have been pretty nearly limited to the British *Vespæ*, and I would restrict myself to these. Though I am not unmindful of the kindness which has made me acquainted with many foreign species, and which has sent me from various parts of the world, from wherever my friends and wasps have crossed each other's paths, materials for the employment of my leisure hours. Perhaps if the letter-carrier knew that many of the little flat packets which he has left at the door contained live wasps he might think that his Christmas-box had been well deserved. However, in justice to my friends, I must say that they were always so well packed that I never incurred a reproof from head-quarters on account of the dangerous nature of my correspondence.

Every country child knows a wasp by sight, if not, the sooner this useful bit of knowledge is acquired the better. To many people this is the beginning and the end of what they know about wasps; to them a wasp is a yellow wasp, a creature with a sting, and nothing more. Yet there are some things

* Smith. 'Catalogue of British Aculeate Hymenoptera,' 1858, p. 196.

concerning wasps which are worth recollecting. One is that wasps, unlike bees, rarely, if ever, sting unless provoked, and that the best way of escaping from them when they are provoked is to retreat to a dark corner or the shade of a tree. Another is that when wasps are killed they should be killed outright and thrown away, for our own sakes as well as the wasps', lest the maimed creatures should revive and crawl up our clothes.

But if we look beyond the mere general resemblance, and examine closely the wasps which come under our notice, we shall find considerable differences among them. Let us over-haul the contents of one of those wasp-traps which are made—and I know of none more effectual—by putting one forcing-glass inside another. First, there may be a good many insects like wasps and bees, which are only wasp- and bee-flies so-called, and not wasps at all. But of the wasps themselves. The several specimens probably differ much in size and form. There is the hornet, which has come to look after the wasps as much as the fruit, otherwise distinguishable by her brown colour, which is much larger than all the rest. Then the perfect females of the smaller species, the future queens, worth so much a-head to little garden-boys in spring and early summer, are much larger than the workers. And the long slight bodies of the drones, or male wasps, can scarcely fail to attract notice. It needs great faith in the statements of naturalists to handle one of these, in the assurance that the slight body and the long antennæ indicate the absence of a sting. But such, nevertheless, is the fact.

Now it is not a very agreeable occupation thus to turn over a heap of half-dead wasps, nor is it altogether safe, unless we look carefully about the while, and, applying to the business in hand the advice of a moralist* on another subject, "eye well those heroes who have held their heads above water, who have touched pitch and not been defiled." But in a little while we may satisfy ourselves, from the study of such a miscellaneous, unsavoury collection, that under the name of wasps are included individuals of very different sizes and forms.

We must not, however, invest every slight deviation from the normal standard, whether of size or colour, with specific importance. For the Hymenoptera are very liable to vary in size, more so than any other Order of insects. For instance, in the same wasp's-nest we may often trace a regular gradation of size from the queen-mother herself to the little cross wasps with their tattered wings which seem, like little old women, to have shrunk up with advancing days. And the same caution about not exalting slight differences into specific distinctions—reversing the terms of the proverb—must be observed with regard to the varieties of colour and marking. We cannot indeed observe too closely, but there is great danger of classifying too minutely. For, besides the broader shades of colour which distinguish a fair wasp from a dark beauty, the actual markings may differ in the inhabitants of the same nest within certain limits; and more widely still in specimens from different swarms of the same species. Like Vulcan's sea nymphs,

* Sir T. Browne, 'Christian Morals,' I, § 12.

“ *Facies non omnibus una,
Nec diversa tamen : qualem decet esse sororum.* ” *

Distinctions of colour and markings, like the differences in the handles of our tools, in the labels on our books, or even in the blots of ink on their covers, are of value as affording a ready means of recognizing the different species at a glance. We see what wasp, or what book we have, at once, from the outside marks, without looking inside. They are of value when they have been shown to have a certain connection with the peculiar habits and internal structure of certain species, because they are more open to observation than these habits and structure. Their value diminishes in proportion as they are more difficult to observe, or less constant ; till, though they are curious, and may have a local interest, they cease to be of any practical importance, as a means of classification.

Distinctions of this kind, to be of any use, should be very exactly laid down ; and this must be my excuse for devoting so much space to what may appear a very trifling matter. With the help of drawings, or labelled specimens, the distinctions are easy enough to trace ; but, without them, mere verbal descriptions are of little use. The parts which bear the characteristic markings are the clypeus ; the neighbouring parts of the face, with the scape of the antennæ ; the dorsal surface of the thorax at its posterior portion ; and the dorsal surface of the first two or three abdominal rings. I propose to point out the characteristic marks which are to be found in each of these parts respectively in the several species,

* Ovid. ‘ *Metam.* ’ II, 13.

as briefly as may be consistent with practical use. And as we are anticipating their regular description, it may be necessary here to indicate what parts are meant by some of the different terms employed.

It is scarcely necessary to explain what is meant by the rings of the abdomen, the thorax, or the antennæ. But it is not as generally known, perhaps, that the scape of the antenna is the first joint, the handle, as it were, of the flail to which antennæ of this form are familiarly compared. The corona and clypeus are parts known only to entomologists by these names; the corona is the little yellow spot between the roots of the antennæ, and the clypeus is the broad yellow central patch which constitutes so large a portion of a wasp's face. The large compound eyes are indented by a deep notch behind the antennæ, dividing them into two portions which are technically called the upper and lower limbs. With this explanation, and by reference to the plates, there should be no difficulty in following the description of the several species.

Of these there are seven. *V. crabro* the great hornet stands alone. Three are tree-wasps, so-called from building by preference in trees or in the open air, namely, *V. britannica*, *V. sylvestris*, and the rare *V. arborea*. The three remaining species, which, as building by preference under ground, are called ground-wasps, are *V. germanica*, *V. vulgaris*, and *V. rufa*. Let us now proceed to examine each of these separately.

V. Crabro, Plate I, to commence with the hornet, differs from the rest in colour as well as size. The

predominating hue is brown, instead of black, and the markings are of an orange- rather than of the gamboge-yellow, which is the familiar livery of the smaller British wasps. The markings lose their special interest in the hornet, as her size and colour present distinctive characters more easy of recognition. But they are, nevertheless, worth attention, because the markings indicate the arrangement of parts within, and the larger size of this insect enables us readily to make out in her what we have some difficulty in tracing in the smaller species.

The antennæ are of a light brown, all the joints being of the same colour. Between them, and rising above the point of their origin, is a yellow patch, the corona, taking the form of the heart in playing cards. Below appears the large convex clypeus, longer from above downwards in proportion than in the smaller species; its uniform yellow surface occasionally broken by a single brown central spot. Below this the large mandibles meet in the mesial line, sometimes overlapping a good deal. Narrowing as they diverge from each other, they are articulated at the other end to the yellow horny rim, which surrounds the whole face, and gives a peculiar expression to the hornet. This margin does not appear in the smaller species because their eyes are larger and the clypeus is broader in proportion.

The markings of the thorax have more interest in an anatomical point of view than as furnishing specific characters. The distinctions in colour appear only as different shades of brown; but they bring out very plainly the position of the divisions of the thorax, which, indeed, are otherwise displayed very strongly

in the hornet. Here, as in the abdomen, we may notice varieties of colour, depending merely on individual or sexual peculiarities and not constituting specific differences. The large convex surface which forms the middle of the thorax has its dark brown relieved by a broad tongue of a lighter colour, corresponding to the position of the great longitudinal muscles of the thorax. This gets narrower as it passes backwards, and is divided down the centre by a dark streak of a thin wedge shape. The different colours are most distinctly shown in the male insect.

In the abdomen, it might appear as if the markings were reducible to two types. But as these distinctions of colour are not connected with any of the variations of size so remarkable in the hornet, nor with any fixed habit of building, nor with any peculiarity of structure whatever, they may be regarded as unimportant, or at least as insufficient to build the distinction of a species on. There is but one British hornet. In this, as in the smaller species, the chief characters are borne on the first and second abdominal rings. The first is marked by a broad band of dark brown, fading gradually as it approaches the edge of the scale, where it abruptly ceases, and a bright yellow line runs along the border. In the lighter coloured specimens secondary lines may be traced within this broad band, and the truncated end of the abdomen has cloudy markings which are lost in the darker insects. In the second ring we have a similar alternation of zones of different shades, shown most distinctly in the lightest coloured specimens. A dark zone sends out a rounded point from beneath the preceding ring, then follows a broad paler band, deepening towards the edge, till

it suddenly changes, as before, into a broad yellow border. The smooth edge observed in the first segment is broken in the second by three projections or cusps; one larger, central, paler; and two smaller, lateral, more defined, and of a deeper colour. These diminish regularly on each successive ring; the central most rapidly. After the third ring the point of the central cusp has generally disappeared, but the square or clubbed ends of the lateral cusps still project from beneath the edge of each preceding scale to the last.

The markings of the perfect and imperfect female, that is of the queen and the worker, are nearly identical, only a little more decided perhaps, as might have been expected, in the perfect insect. The central cusp in the worker is rather more pointed and proportionally longer. In {the male—the drone—the central cusp is much less prominent, and is rounded rather than pointed. And the specific characters scarcely come out till the third segment, instead of appearing, as in the females, on the second.

The six species of smaller wasps are all nearly of the same size, except *V. vulgaris*, the workers of which are generally rather below the average dimensions of the others. And they are all nearly of the same colour, except *V. britannica* and *V. rufa*, which have certain patches of an orange hue mixed with the regulation black and yellow uniform. The distinctive markings are to be looked for on the clypeus and the two first abdominal rings, as in the hornet. But, besides these, a most important distinction is to be found in the colour of the scape, the long first joint,

of the antennæ, by which they may be divided into two classes. In all the sexes of all three species of tree-wasp the scape is yellow in front. In the ground-wasps the antennæ of the females and workers are black all over, only the males having yellow scapes. We must not say at once that because a wasp has a yellow scape she never builds in the ground, for *V. sylvestris* seems to build above or underground indifferently, notwithstanding her yellow scape. And other exceptions are constantly occurring. But still, as a general rule, the colour of the scape in the female Vespæ indicates their habits in this particular very exactly.

V. britannica, Plate II, one of the tree-wasps, is generally easily recognized by her dark appearance, but she has besides some very well marked distinctive characters. The face is very dark, the bounding yellow line of the compound eyes being almost too fine to be seen, and the only relief being given by the scapes, the small corona, and a comparatively small portion of the clypeus. This last is divided from top to bottom by a broad black line, swelling out on either side into something of the figure of a spear-head pointing downwards, the angles being more or less acute in different specimens. The corona is small, and is divided into two lobes by a deep notch both above and below. Alone, of all the species, the face of this wasp is quite unmistakeable.

Turning to the dorsal aspect of the insect, we find on the vertex of the head and on the thorax but few distinctive marks. For the two yellow spots which appear on the metathorax, one on either side, are

common to the other tree-wasps as well as to *V. rufa* also. Again, the yellow lines which converge from the root of the wings on either side to the back of the head, the yellow triangular spots beneath the wings, and the yellow line visible on this aspect behind the upper limb of the compound eyes are common to all the species. They are of use in distinguishing these Vespæ from others, but between one British species and another they have no significance.

The truncated end of the abdomen is black, and a band of this colour is extended a little beyond the square edge where the dorsal aspect begins. In the middle this black marking comes down in an obtuse angle. At the sides it slopes off in an even line, except where it is encroached upon by an orange-coloured spot. The yellow border of this ring has also a very decided orange tint. The second ring, in the same way, presents a bluntish cusp in the centre, but, instead of narrowing from this point, the black band sweeps down, in a saddle shape, to the two lateral cusps, which are square, not pointed, at the end. Then it suddenly turns up, and in the notch thus made a bright orange spot is generally to be seen. The central cusp disappears in the succeeding rings; and, as the band becomes narrower, the ends of the lateral ones are disconnected with it and stand out as isolated black spots on the yellow ground.

The male has the same markings on the face and thorax as the female. But the orange spot on the second abdominal ring is more decided in this sex. The black bands are of a more uniform width, and their outline is less broken by the projecting cusps. Sometimes the female of this species is covered with

long black hair, so as to present quite a rough furry appearance.

V. sylvestris, Plate' II, is a larger insect than the preceding, and of a lighter colour; she stands higher, and is altogether the most beautiful of the British social wasps. Commencing, as before, with the female: her clypeus is marked with a single dark spot in the centre. A fine yellow line runs round the inner edge of the compound eyes, and the corona is a more prominent feature than in *V. britannica*. This is larger; its upper edge is slightly hollowed out in the middle; two little notches are seen on each side; and the outline of the lower edge is broken in the centre by a round hole being gouged out as it were. These figures need a lens to trace them, but they give very important differential characters.

The thorax resembles that of *V. britannica*, and so, but for the absence of the orange tint, does the first abdominal ring. The second ring is more distinctive. There is a broad black band, gradually narrowing from the central point, the regular sweep of which is but little interfered with by the slight projection of the angular lateral cusps. And these slight projections rapidly disappear in the succeeding rings. The male differs from the female in the more uniform width of the black bands on the abdominal rings; they contract less from the central point, though their sweep is more broken by projecting lateral cusps. These are most distinct in the worker. The central point on the first ring is more prominent in the male insect.

V. arborea, Plate III, is represented in my cabinet, as in most others, by the female only. She is shorter and not of such elegant proportions as *V. sylvestris*. The clypeus is marked by three little streaks, radiating as it were from the upper edge of the commissure of the mandibles, the central streak being the smallest. There is a yellow line just edging the lower limb of the eyes. The corona is large, deeply notched in the centre, and with a smaller notch on either side on the upper edge; the sides are straight, converging to the lower edge, which is slightly hollowed out.

The thorax is marked as in the two preceding species, but the markings of the abdomen are very peculiar, resembling closely those of *V. rufa*. But while in this the orange yellow, as its name indicates, is very decided, the gamboge hue is more distinct in *V. arborea* than in any other of our species. The first abdominal ring presents three transversely-oval black spots, which are sometimes connected to each other by a faint shade. The lateral spots are isolated, but the central spot is connected by a root with the central cusp of the dark band which just shows over the square edge of the upper portion of the abdomen. In the second ring the black band is spread out into a central cusp, on the top of which stands an oval spot like a button on a cow's horn. Below, on either side, is an oval spot, corresponding to those noticed on the first ring, but very much smaller, and, as in the species already described, rapidly disappearing in the succeeding rings. An indistinct shade connects these spots with the central cusp, and sometimes a faint line runs up from them towards the sides,

enclosing a diamond-shaped space, similar to what we find so strongly marked in one variety of *V. rufa*.

I am indebted to the kindness of Mr. F. Smith on this as on so many other occasions, for the opportunity of completing this series of illustrations from his specimens of the male and worker of this rare species. It will be seen, from the drawings, that the markings of the male differ little from those of the perfect female. In the worker the distinctions are more marked, the central spots or buttons on the abdominal scales being drawn out, as it were, into angular cusps, somewhat in the way that we shall find those of the worker of *V. rufa* to be.

Turning now to the ground-wasps:

V. germanica, Plate III, in the person of the queen, attains perhaps a larger size than any other of the small British wasps. She herself is at once distinguishable from the queen of *V. vulgaris*, but the males and workers of these two species are not always easy to be known apart. The clypeus has three black spots, but the middle one often exceeds the rest in size, descending from the top of the clypeus as a broad black line. Instead of her having only a narrow edging to the lower limb of the compound eyes, nearly the whole space between the limbs is filled in with yellow. The corona seems to spread out into two horns, the upper edge being widely hollowed out; the sides descend straight, slightly converging; and the lower edge is concave, with a central angular notch.

The thorax presents four yellow spots, two on either side of the metathorax, the hinder pair being

much the smallest. In this species, as in *V. arborea*, the black band scarcely reaches beyond the edge of the dorsal aspect of the first abdominal ring. The broad yellow dorsal surface is broken by three black spots. Of these the central spot is the most conspicuous; it is diamond shaped with the angles somewhat rounded off, and extends quite from one edge of the ring to the other. The lateral spots are oval, closely attached to the black band, and not extending as far as the central one towards the edge of the ring. In the second ring a narrow black band appears on the dorsal surface which rises in the middle into a long dome-shaped cusp bulging out at the sides. The two lateral spots are round, and quite unconnected with the black band. In the successive rings the lateral spots stretch out into transverse streaks, while the central cusp is thinned down into the more usual pointed form, hollowed out at the sides.

The markings of the abdomen of the worker differ notably from those of the queen. The diamond in the centre of the first abdominal ring is smaller in proportion, and the angles sharper; the lateral spots are also smaller, and more distant from the centre. In the succeeding rings the same sharpness of the angles appears, the dome-shaped central marking on the second having the outline often broken by the projection of a point on either side. The markings on the male are still smaller in proportion than those of the worker, especially those on the first abdominal ring. Their form is intermediate between those displayed in the queen and the workers respectively.

V. vulgaris, Plate IV, is sometimes most inconveniently known by the name of the anchor-faced wasp, from the form of the markings on the clypeus. She shares this appellation with *V. rufa*. There is a broad line down the centre of the clypeus, swelling out at the bottom on either side into a form more resembling the battered head of an old wedge than the arms of an anchor. Sometimes the black marking stops here, at others it contracts into a narrow line which is continued down to the lower edge of the clypeus, as in *V. britannica*.

The corona is large. There is a deep central notch on the upper edge, which curves outwards from this point in a continuous sweep. The sides are straight, and so are the two lines which, meeting in a shallow central notch, form the lower boundary. The form of the corona, however, like that of the marking on the clypeus, varies considerably in different specimens. One of the most common varieties is the presence of two little cusps, or perhaps isolated dots, beneath the lower edge. As in *V. germanica*, the space between the limbs of the compound eyes, in front of which the scape of the antennæ lies, is uniformly yellow.

The metathorax is marked with two, or sometimes three pair of symmetrical yellow spots, rather smaller than those which are found in the species last described.

The first ring of the abdomen has a broad black band curving down regularly to a central point, the outline unbroken by any projecting lateral cusps. The markings of the second ring much resemble those of the hornet, and, as in that species, there is

an alternation of light and shade; the black polished band which underlies the preceding segment being followed by a lighter coloured band before the distinctive marking begins. A central point and two lateral square cusps distinguish this species; the point shrinking, and the squares separating from the black band, in the succeeding rings.

There is no difficulty, as has already been said, in distinguishing the queens of *V. vulgaris* and *V. germanica* from each other, but the males and workers are not always readily to be referred to their respective species. The first segment of the abdomen in the worker of *V. vulgaris* displays only a very narrow black band on its dorsal aspect, and the central marking is diamond-shaped, with the lateral angles much elongated. In some workers of the two species the markings of this ring are absolutely the same. The saddle-shaped marking, which begins in the second ring of the queen of *V. vulgaris* does not begin till the third ring of the worker; and that which this worker usually bears in her second ring is very like the marking of the worker of *V. germanica*. The male would be still more difficult to distinguish did not the form of the sexual* organs supply an unerring differential character under the microscope. When *V. vulgaris* has her typical saddle-shaped mark on the third ring, and that on the second ring of *V. germanica* does not deviate far from the figure of a dome, there is no difficulty; but when the black central mark shrinks in the first- and spreads in the last-named species, and the lateral marks of *V. vulgaris*

* Smith. 'Catalogue of British Hymenoptera,' 1858. Vespidae, Plate V, figs. 20, 21.

appear as dots separated from the black band instead of cusps, the grounds of distinction are almost lost. And when besides, the face markings are not decisive, in such a case, away from one's books, and specimens, and microscope, it is absolutely impossible to say to which species a male or worker of either of these rightly belongs. The best entomologist would be puzzled to sort a handful of these wasps under such circumstances.

V. rufa, Plate IV, presents several varieties of marking. The queen, who is much larger in proportion to her subjects than the queens of the other species, has the figure of an anchor very distinctly traced on the clypeus, the shank being placed vertically, with the arms turning up on either side. There is only a thin yellow line along the margin of the eyes, the corona standing in a dark space. This presents a deep central notch on its upper edge, dividing it into two arcs. The sides are straight, the lower edge concave.

The thorax presents seldom more than one pair of yellow spots on its posterior surface. In the first ring of the abdomen the black band does not extend beyond the square truncated end. In the centre of the dorsal aspect of this ring is a dark oval spot, elongated transversely, darker where it first rises into view from the black band, and shaded off at its edges. A reddish shade spreads out on either side to join it to the lateral spots, which look like the two halves of the central spot repeated at the extreme ends of the dorsal scale of the segment. Sometimes, instead of these three spots, the connect-

ing shade is deepened into a continuous transverse stripe of black, the square edge of the ring displaying two short bright yellow streaks instead of the usual interspaces between the spots. In the second ring the black band sweeps down in a curve to a central cusp on which a button is placed as in *V. arborea*. The two small lateral spots are connected with this central button by fine reddish lines, and the edges of the button have a rufous or orange shade. This rufous shade descends towards the tail, enclosing the lateral spots, then rises to meet a cusp projecting from the black band near the extreme end of the dorsal scale. A smaller cusp like this is found in the same place in *V. arborea*, where we have already noticed a similar disposition of the light and dark shades; but in the other species it is scarcely to be recognized. In the succeeding rings the button is merged in the cusp, which appears in a dome shape, still giving off the reddish lines to the lateral spots. In darker specimens of this species, as of the hornet, all these delicate markings are lost, the rufous shades are replaced by broad dark lines. It is curious that De Saussure,* in his beautiful figures of the *Vespæ*, should have selected a dark specimen of *V. rufa* as a typical illustration; while Curtis,† in his no less beautiful series of illustrations, has selected a specimen with as bright tints as are ever to be seen. Both are equally correct as illustrations; and are apposite warnings at the same time of the difficulties which we may expect to meet with, in spite of the best written descriptions, even with, the aid of figures, in determining species.

* 'Guêpes Sociales.' Planche XIV.

† 'British Hymenoptera,' reprint, 1862, Plate 760.

In the worker the abdominal marks are less distinct than in the queen, and smaller in proportion to the size of the insect. The central button on the second ring is narrowed down to a simple streak with a red shading round its point. The markings of the male, as in *V. arborea*, nearly resemble those of the perfect female.

It would be scarcely worth while to lengthen this work in, to me at least, its most tedious part by going over this ground again, and reproducing the distinctive character of the several species in the form of a tabular analysis. Useful as such an arrangement is when the species are numerous, it is scarcely required when there are no more than six. And it would probably need nearly as much pains to master such an arrangement as to construct one for oneself. I would, therefore, only observe that the distinction of spots or figured markings on the clypeus, and of the different forms of the markings on the first abdominal ring may readily be tabulated so as to show the several species. But the same pains spent on the comparison of one or two specimens with each other, or with accurate drawings, would be a much more useful exercise than the construction of an analytical table; and would help more towards a solution of real difficulties when they do arise.

Regarding the subject now from a somewhat different point of view. Except in the different styles of architecture displayed in the construction of their nests, which will be more conveniently examined in another place, there is very little in the habits of the smaller species of wasps to distinguish them from one

another. One seems, indeed, to find certain peculiar traits of character in the different species, when one has had the opportunity of watching them closely for some time; but perhaps these distinctions may be imaginary. *V. sylvestris* is the most powerful, and is said to have the sharpest sting. I do not know how this may be, but *V. vulgaris* knows best how to use it; and I would far rather attack a nest of the bold open enemy than of the persevering little wretch which works her way between all the joints in ones armour. *V. rufa* is said* to be particularly gentle, to hold the place among wasps which the humble bee has among bees. But of the habits of this wasp I have no personal knowledge.

Only the hornet has a history of its own. A mysterious dread has connected itself with the name of this insect which, doubtless, its mention in the Bible† as the scourge by which the nations were gradually driven out before the Israelites, tends to maintain. As we do not now, in Europe, under its present circumstances, recognize in the hornet such a powerful instrument of destruction as this would represent, the exactness of the translation has been questioned, and Bruce's African *zimb* or *tsetse*‡ has been suggested as a better rendering.§ We must remember, however,

* Edgeworth on Irish Vespidae. 'Annals and Magazine of Natural History,' 3rd Series, Vol. XIII, p. 472.

† Exodus xxiii, 28. Deuteronomy vii, 20. Joshua xxiv, 12. Wisdom of Solomon xii, 8, has the word Wasps.

‡ Livingstone's 'Travels in South Africa.' Small 8vo, 1861. p. 56.

§ See notes of 'Pictorial Bible,' on Joshua xxiv, 12, favouring the claims of the *zimb*. Smith's 'Dictionary of the Bible,' Article Hornet, receives this word in a metaphorical sense, as equivalent to a

that the translators of the Septuagint and Vulgate had, at least, as good means of information on this point as we have now. In particular, Jerome, the author of the Vulgate translation, lived for many years in the neighbourhood of Jerusalem, and would, doubtless, have used another word instead of *Crabro*, hornet, had he not thought that the hornet was intended in the original text.

It is true that we cannot assert that there was any great precision in the use of terms of natural history in the Greek language, which included under the one name of *στρουθός*, a sparrow and an ostrich. And *σφήκτα* was probably a general term for all, wasps and hornets alike, in Greek, as *Crabro* certainly was in classical Latin. Perhaps, in accordance with this usage, the original word in the Bible might have been meant to include all stinging insects that fly; just as, apparently, all stinging insects that crawl on the ground are called scorpions.* Still, in the Bible, a distinction is observed between various insects. For when the remote Egyptian fly is mentioned, the terms in which the plague is spoken of clearly distinguish it from the hornet, as well as from another stinging insect which comes from a nearer quarter, namely, the Assyrian bee.† And really there seems to

fear or a terror, citing the word *æstrus* as a parallel instance. The converse instance of *bug* might also have been cited, Psalm xci, 5, as pointed out in that admirable little book 'Gosse's School Zoology,' p. 158, note. The article Hornet in the 'Bible Cyclopædia,' 2 vols, folio, London, 1841, asserts the literal correctness of the text, and supports this view by well chosen illustrations.

* Deuteronomy viii, 15. Revelation ix, 3—10.

† Isaiah vii, 18. The fly that is in the uttermost part of the rivers of Egypt, and the bee that is in the land of Assyria.

be no occasion to divert the word from its literal meaning, as it stands in our translation. For there were hornets in Palestine in Joshua's time. The name Zoreah "the place of hornets," a city in Judah's inheritance, records the fact.* The latest travellers assure us that hornets are to be found in abundance throughout the country;† and among their collections I am told that our own English hornet is to be recognized. Mr. Tristram, whose delightful book has given yet a fresh interest to the Holy Land, and to whom naturalists owe a debt of gratitude for clearing up the difficulty about the Unicorn by discovering the bones of the Aurochs,‡ has not left this question of the hornets unnoticed. He found four kinds of hornets, all, he says, different from our indigenous species, two building in the air like our tree-wasps and hornets, and two underground. They were decidedly larger than ours, and one of their combs measured 18 inches across. Quiet when unprovoked, the fury of their attack when they are disturbed makes a hasty retreat the only preventive of a complete rout of the camp.§

It should be observed that, for the most part, objections are not made to the Scripture assertion that

* Joshua xv, 33.

† 'Stanley Lectures on the Jewish Church.' 2nd edition, vol. i, p. 212.

‡ 'The Land of Israel.' 2nd edition, p. 11.

§ 'The Natural History of the Bible,' p. 322. To the expression of my admiration of Mr. Tristram's labours in Scripture Natural History, I must add my grateful sense of his courtesy in giving me every information in his power on this subject. Naturalists look forward with great interest to the publication of his scientific work on the 'Fauna and Flora of the Holy Land.'

the remains of the nations were driven out by such means, but only to the specific insect by whom this expulsion is said to have been effected. The closer, however, the subject is examined the more competent do the hornets of Palestine prove to be to the task; and, indeed, the rival *tsetse* would appear, by comparison, a much less direct and much less powerful enemy than the hornet. A less obviously alarming insect, such as a fly, or a flight of locusts, or a pestilential vapour might have been chosen as instruments to drive out the Amorites. But, as it was, the indigenous hornets were selected to expel them gradually and quietly, and then, in their turn, gradually to give place to the advance of the Israelites coming to take permanent possession of the Promised Land. In strong contrast with the simple Bible narrative, the point here being the gradual expulsion of the nations by this pest which they could not exterminate, stand the accounts in various authors,* of armed hosts being routed or thrown into confusion by similar agencies. But the touch of the marvellous which is introduced into the accounts I am now alluding to, as far as I have been able to examine them, is scarcely sufficient to exclude the sense of the ludicrous. The result, taking these as reported, on the credit of the several historians, should, however, be ascribed rather to the defenceless state of the armed men than to the power of their winged adversaries. Sword and spear would be as useless against wasps as the lion's paw, in the

* See the references in the articles cited above in the 'Pictorial Bible,' Smith's 'Dictionary of the Bible,' and 'Bible Cyclopædia.' I have not been able to verify all these personally.

fable, against the gnat. The proper armour, offensive and defensive, would have been found in Birnam Wood.* Still, with all the resistance that science and hardiness could offer, a large surveying party has been driven off by a seemingly much more contemptible enemy than wasps, within the few last years, "We were fairly vanquished—the labour of a hundred men, and as many mules and horses put an end to by tiny flies."†

I alluded just now to the competency of the hornets of Palestine to the task assigned to them. The common Indian hornet *V. cincta*, which, with *V. orientalis*,* as I am told, is found in Syria, is altogether a much more formidable enemy than her British representative. Dr. J. B. King, of Penang, to whom I am indebted for many specimens of Indian Entomology, tells me with reference to this wasp, October 17, 1863,—“He is very vicious, and we are all in great fear of him. No later than last Sunday one flew into the Scotch kirk where one of the merchants was reading the service, plumped down and stung him instantly on the head, and was off again in a moment. The sting drew blood besides being excessively painful. I was once stung by two of them, while riding at a foot’s pace by their nest, on the back of the head. The pain was most severe. Tenderness down the neck and in the part

* Macbeth, Act V, Scene 4.

† Lord. ‘At Home in the Wilderness,’ p. 277, in reference to the mosquitoes. The sand-flies, p. 285, seem even more to be dreaded, by mules at least.

‡ Figured in Drury’s ‘Illustrations of Exotic Entomology,’ edited by Westwood, Vol. II, plate 39, fig. 1.

remained for more than two weeks afterwards." Probably, from the appearance of the nest, it is in reference to the same or an allied species, that Major-General Sir Thomas Seaton* has a story to tell about the condition of a sugar store at Shahjehanpore, which had been left for some weeks in possession of a swarm of hornets, who had taken and held it in defiance of the Government. At the end of the season, when the Commissariat Officer ventured to return and claim his charge, it was found that nearly 3,000 pounds of sugar had been consumed by them. Further on, he tells us of a picket of Lord Clyde's army, who were amusing themselves by throwing stones at an odd looking mass of mud and straw hanging on a tree. One marksman more successful than his comrades, sent a stone with great effect into the centre of the mysterious object, and out flew a cloud of hornets which drove Lord Clyde's invincibles into the river.

Hornets, however, at least our Anglo-Saxon breed, improve on acquaintance. Like dogs, they have great powers of annoyance; but, like dogs, they are slow in using them except under provocation. The advice is very good, *crabrones ne irritare*, but this maxim should be indorsed with another, leave them alone and they will leave you alone. Westwood† says that the Americans sometimes introduce the nests of hornets into their houses, to keep away flies. Mr. Gravely, of Cowfold, told me of a poor woman whom he attended in her confinement, who had made friends with a swarm of hornets which

* 'From Cadet to Colonel,' 1866, Vol. II, p. 314.

† 'Modern Classification,' Vol. II, p. 246, note.

had built in her cottage roof, and who reiterated her assurances of their perfect harmlessness as, attracted by the light, they flew blundering about his head. But the hornets have found their most genial historian in Pastor Müller,* who has written a most interesting account of the proceedings of a swarm which he observed from the commencement.

In the beginning of May, 1811, he observed a hornet making a nest in an empty bee-hive. The nest at that time consisted of a hood over seven cells, none of them containing eggs. However, the eggs were soon after laid, and the brood began to appear on June 15. He could observe all the proceedings of the queen, and calculated that about eight or ten seconds were occupied in the deposition of each egg. The growing swarm now endeavoured to close in the nest below, but the familiarity which he had acquired with them enabled him to break away the case as fast as they built it, and thus to keep the interior exposed to view. By killing some of the larvæ, which the workers immediately removed, he contrived to keep the numbers within bounds. His pets had reached the number of fifty or sixty, and the drone brood were coming forward when, one unhappy day, the queen was lost. She had continued to fly in and out all the time, but this day she did not return, and after her loss the swarm dwindled away. His hornets knew him, and used to let him handle them and carry their nest about; those who were out when the nest was taken away waiting on the hive-board till its return. We shall

* Beiträge zur Naturgeschichte der grossen Hornisse. 'Magazin der Entomologie.' Gernar. Halle, 1817. Band III, s. 56.

have occasion to recur again to the observations of Pastor Müller, as well as to those of Mr. Newport,* who had a similar opportunity of watching the progress of an infant colony of hornets. His observations, too, were cut short in the same way by the untimely death of the queen.

* On the Habits and on the Structure of the Nests of Gregarious Hymenoptera. 'Trans. Entomolog. Society of London,' Vol. III, p. 183. 1841—43.

CHAPTER III.

ANATOMY AND PHYSIOLOGY.

TEGUMENTARY SKELETON. HEAD. EYES. ANTENNÆ. MOUTH: ITS
DETAILS AND COMPARATIVE ANATOMY.

I DO not propose to enter here into a detailed account of the anatomical structure of wasps. I would limit myself to the notice of the points in which wasps as a class differ from those insects to which they are most nearly allied; of the parts which supply their most important distinctive characters; and, summarily, of all those organs by which they are peculiarly adapted to their place in the scale of nature. Not that there is anything in the structure of these tiny organisms but what has an intimate relation and due proportion to the other parts, and to the purpose of the whole. There is, indeed, nothing that we can really regard as unimportant, there is nothing to spare in an insect, any more than there are any wheels to spare in a piece of watchwork. But there are some parts which have a more obvious importance, as being the apparent means by which the little creature is fitted to the sphere assigned to it.

In carrying out the proposed plan, I do not feel sure that I have always adopted the right mean between the two opposite dangers of saying too much or too little ; of telling what few might care to be told, or no more than what every one who feels an interest in the subject already knows. And as to how this should be told. Probably, no amount of literary skill in the selection and arrangement of materials could render bare anatomical details anything but dry. So, where the minute examination of any part has appeared indispensable, at the risk of seeming discursive, I have tried to make the description clearer and more interesting by introducing such illustrations as the corresponding structures of other familiar insects afford. The illustration which naturally suggests itself to contrast or compare with the wasp is the honey-bee, both in her habits and her anatomical structure. With regard to this insect, I must own to having reversed the order of Swammerdam and Réaumur, by both of whom the first place of honour and affection is always assigned to the honey-bee. But I speak as I find. Wasps never attack me if I leave them alone, or handle them with discretion ; but bees, conscious perhaps, that the working hours of an anatomist were not spent among flowers, used to repel all my attempts to become better acquainted with them. So wasps have been my Grammar of Entomology, instead of the more popular but more capricious insect. I confess, that in the uncertain state of my relations to bees, I only feel quite secure in watching them when, to the latest improvement in glass hives, there is added a room for the observer quite inaccessible to angry

fastidious bees. For the free use of such a beehouse, and for unfailing supplies of bees, I have great pleasure in acknowledging my obligations to Mrs. Eardley Hall, of Henfield.

The structure of the Hymenoptera is peculiarly interesting, and has always occupied a prominent place in treatises on the Anatomy of Insects. I would refer those who may be desirous of more and more exact information on the details of this subject than I can give or find room for here to the works of Newport* and Burmeister.† On very difficult points I have preferred to refer to their descriptions, rather than to speak from the partial and imperfect appearances of my own dissections. In matters of which anyone with time and patience may master the details I have not consciously leant upon their assistance except to confirm my own observations.

There can be no doubt about the part with which the description should begin :—

The skeleton on which the soft tissues are hung, the frame which gives form to the animal and supplies the necessary points of resistance to the action of its muscles, is, in insects, placed outside. Their horny skin is also their skeleton. It has been disputed whether this integument should be regarded as skin or bone. Its anatomical structure certainly rather favours the first conclusion.‡ The laminated arrangement, and the form and position of the com-

* 'Cyclopaedia of Anatomy and Physiology,' article *Insecta*.

† 'Manual of Entomology,' translated by Shuckard. 8vo. 1836.

‡ 'Catalogue of the Histological Series,' College of Surgeons' Museum, Vol. I, p. 246.

ponent cells forcibly recall the structure of the cuticle of the higher animals ; and the rudiments of a three-fold division into cuticle, rete, and cutis agree with this comparison. But the functions of this integument, so especially mechanical, and the permanent nature of the segmental sub-divisions, have more weight in the eyes of physiologists ; and general opinion inclines to regard it as insect bone.

The body of the larva is covered with a thin, soft membrane which has no more strength than is sufficient to retain the form of the almost diffuent embryo. But the lines by which this skin is indented, the thirteen segments into which it is divided, have a singular physiological importance. These segments are almost unvarying in number throughout the insect kingdom, the singular exception being found in the Hymenopterous order, with which we are now concerned, where a fourteenth segment occurs. They bear a definite relation to the parts of the perfect insect, and are all, as we shall see further on, more or less exactly represented there. The thin pellucid membrane which envelopes the wasp-grub has to undergo very important changes before it becomes the tegumentary skeleton of the perfect wasp. But the changes are all transacted within the cell. When the insect emerges from the cocoon her skin is as perfect and as changeless as the rest of her structure. The integuments need only to harden and dry, and have their colours brought out by the light, to become such as they are to continue for life.

As this covering cannot grow, so neither can there be any growth of the insect. A wasp may

seem to be larger or smaller, according as the scales of the abdomen are drawn out or retracted, but the frame does not alter; and indeed the only permanent change of the perfect insect is a constant shrinking up and diminution of size with advancing days. The wasp is no exception to the ordinary rule of insects; the skeleton has no means of growth any more than of repair. The *seeming* exceptions to the rule, where the form of the perfect insect is maintained throughout life, and is put on before the great final change is accomplished, are not found among flying insects. Little bugs and little cockroaches are early endued with the form which they are to bear for life, and within this frame they carry the materials and organs by which they are to be developed, by successive stages, into more and more perfect insects. But flies, butterflies, and wasps do not take their aerial form till they are past change, and can rise unburthened into their proper element. The variations in the size of the Hymenoptera are due to original development of the pupa, not to later growth of the perfect insect.

The integument of the wasp, as of other insects, is composed of *chitin*, a substance resembling horn in some of its mechanical properties, but totally unlike it in structure and chemical composition. Chemically examined, chitin* is found to be insoluble in a solution of caustic potash; it does not swell up and melt before the flame of the blow-pipe, but burns away into a white ash composed of phosphate of lime and iron, with carbonate of potash. And the cover-

* 'Cyclopædia of Anatomy and Physiology,' Vol. II, p. 882. See also Lehmann, 'Handbuch der Physiologischen Chemie,' Leipzig, 1859, p. 192, on the Chemical Affinities of Chitin.

ing of insects, instead of displaying under the microscope the fibrous texture and the peculiar refractive properties of horn, has a wholly different structural arrangement. Taking one of the abdominal scales of a wasp, we find in this two distinct layers closely connected together. First, there is an outer hard layer, which bears the beautiful varied colours of the insect; beneath this is a thinner and softer layer, which, when dry, becomes brittle, and can be separated in the form of small flakes. The smaller hairs, which clothe the surface of the body, cannot usually be traced deeper than the outer layer, but the larger hairs may be followed through it and the inner layer, into contact with the soft substance beneath; probably supplying the necessary amount of cutaneous sensation in this way. By ordinary light it might seem that the inner layer was perforated by these hairs, giving it what anatomists call a cribriform appearance. But this is incorrect; the hairs are a part of this layer, growing from it. And polarized light shows that these seeming perforations are really not holes, but transverse sections of the shafts of the hairs, with a concentric laminated structure, which refracts the light in crosses, in the same way that whalebone or rhinoceros-horn does.

Within this hard case the soft tissues of the wasp are carefully inclosed. To these walls, or to ridges springing from them at the junction of the several segments, the muscles are attached which move the body. And, according to the mode in which the edges of the adjoining segments are fitted to each other, is the rigidity or flexibility of that part of the body secured. Considering the work

which wasps have to do, and the circumstances of their daily life, no covering could be devised more exactly adapted to their wants than that which they possess. It is hard and resisting, yet as sensitive as our hard teeth; and, since the perfect insect has no means of repairing the injuries which it may receive, it is made as little liable to injury as possible. It is rigid or flexible in different parts, according to the uses of those parts, but, still with due regard to the life which the wasp leads, this flexibility is not gained by weakening the defensive armour more than can be helped. Many insects have unguarded points, but the wasp carries a complete coat of mail. In the structure of her limbs the wasp displays, in common with all other insects, the object of the skeleton being placed outside. In no other way could the same amount of material have been disposed to equal advantage according to mechanical laws. A larger surface is thus obtained for the attachment of the muscles and for the articulations. And, by the skeleton answering the double purpose of skin and bone, all the weight of the former is saved.

The three great divisions of the insect body, which give this class of animals their peculiar form and their name, are singularly distinct in wasps; the head, thorax, and abdomen are readily separable from each other. It will be more convenient to follow these natural divisions, and to examine the chief organs contained within, or connected with each of them successively, than to study each system of organs separately, as a whole.

Commencing, therefore, with the head, which corresponds to the first larval segment:—The chief parts to be noticed here are the eyes, the mouth in all its details, and the antennæ. The horny skeleton to which these are attached has different names in different parts: the elementary divisions of the head, however, have not in wasps the same importance as those of the thorax have, and we need not dwell on them at length. The face is a more intelligible expression as applied to wasps, which have the head set at right angles to the axis of the body, than to many other insects. Beetles, for instance, have the mandibles projecting forwards, and their face is on the same plane as their back, the vertex of their head being buried in the thorax. But the vertex of the wasp's head, as she stands, is its highest part.

There seems, at first, little to notice in this round dark downy surface; but if we look closely we shall see three little shining points, black, or occasionally marked with yellow, set in the form of a nearly equilateral triangle with the apex pointing forwards. These are called the ocelli, or simple eyes, to distinguish them from the large compound eyes which stand out from either side of the head of the perfect insect. The larva has only simple eyes; these, however, are not the ocelli, but the rudiments of the compound eyes, into which they are developed, and like which they stand, two in number, one on either side of the head.*

The eyes of insects have been most successfully studied by Müller,† whose description I propose to

* Westwood. 'Entomologist's Text-book,' p. 184.

† 'Burmeister Trans.,' pp. 289–295.

follow. The ocelli, or simple eyes, have many of the same parts as are found in the eyes of some of the higher animals, but in a rudimentary condition. The cornea or horny membrane, which forms the outermost covering of the organ, is a continuation of the general integument and laminated like it, only made transparent. Behind this is a regular lens, with a rudimentary iris round its edge. The light enters the centre of the lens through the pupil and, traversing it, is received on a crystalline body which lies immediately behind, in contact with the optic nerve.

The optical arrangements of a perfect eye are to be traced here, but in a very rudimentary form. A still simpler optical instrument is presented in each of the units which go to make up the compound eyes. In these the conical crystalline body, which is in contact with the optic nerve, is continued direct to the cornea, or the horny covering, without the intervention of any lens or iris whatever to modify the image or control the admission of light. Each of these crystalline cones is an eye in itself, separated from the adjacent cones by a layer of dark colouring matter. Corresponding to these, the common cornea is divided into a number of hexagonal, or sometimes quadrangular, facets—many hundreds altogether—each a bi-convex lens of a definite curvature differing according to its position. Besides the protection which the hardness of the cornea supplies to the soft delicate structures beneath, some insects, as the honey-bee, have the septa between the facets of the cornea armed with hairs—eyelashes as it were—placed so as to protect the eyes without obstructing vision.

On abstract optical principles it is inferred that these two kinds of eyes have different properties. The single eyes, constructed like those of fishes, are intended, like those, for near vision. The compound eyes take in distant objects and a wider field; distinctness being secured by the spaces into which the picture is divided; and the extent of the field being in direct proportion to the extent of the surface of the cornea and to the degree of its convexity. An experiment shows so very little, that one would rather trust to general observation and to the anatomical examination of an organ, than to any conclusions from experiments, as to its functions. However, experiments have not been wanting* on the question of the nature and functions of the parts which we call eyes. And by coating them with black varnish the same conclusions were reached which have been more surely attained by inference from their structure and optical arrangements.

The eyelashes of the honey-bee, just alluded to, are supposed to add to the distinctness of vision by separating the different parts of the mosaic pattern which is impressed on the retina, and thus localizing more exactly the objects in the field of view.

Such are the descriptions of Müller, and the conclusions which he has drawn from them. They are not, however, universally accepted in all their details. For some anatomists suppose that the structure of the units of the compound eyes is more elaborate, and that they have a higher function than Müller has

* See a notice of these experiments in Van der Hoeven's 'Hand-book of Zoology, translated by Dr. Clark,' Vol. I, p. 280.

assigned to them.* I can offer no opinion on this point, but, with others who scarcely can bring themselves to think that such accurate observers can be really at variance, I would willingly believe that these differences in the description of the eyes of insects by different anatomists are founded in fact, not in error of observation. The description of the eyes in one insect—if it is not presumptuous to offer any suggestion—so correct in all its details, need not necessarily coincide with the microscopic lineaments as carefully traced in another insect. Varied as the organs of insects are in every way, so exactly adapted in every particular to the wants of each of them, it is scarcely to be supposed that the eyes of them all would be identical in structure, and that the description of one would be applicable to the whole class.

I have spoken of a more or less perfect form of structure. Let me qualify this expression, for it is one which there is often occasion to employ, and Entomology teems with illustrations of the fact, that what we might term defects are really, in relation to the whole animal, perfections. Perfect adaptation, not abstract perfection, is maintained throughout. A watch without any works at all is just as good for a child to wear as a chronometer. The perfect long-sighted eye of a bird, with all its wonderful adaptations, would be worse than useless, even had it yet another adaptation to enable it to act in water, in the mantle of a scallop. A little Crustacean, the whole thickness of whose microscopic body is permeable by chemical diffusion, needs no mechanical

* See 'Cyclopædia of Anatomy and Physiology,' Vol. II, p. 960.

aids to respiration. And so its respiratory organs are less perfect than those of creatures which are below it in the scale. Our own structure may point another illustration. A perfect vertebra, such as many fish possess, would be terribly in our way, with the anterior spinous process sticking out in front. And our perfect hands and feet would sadly interfere with the perfect adaptation of the seal and porpoise to their several spheres of existence.

So, in speaking of anything being imperfect, it must be understood that this term cannot be applied absolutely and unreservedly concerning any animal structure. Everything in creation is perfect for its purpose. But the structure of each part is always adapted, subordinated, to the necessities of the animal. Each organ is always made as good as it is wanted, but no better; for a more elaborate structure is more easily deranged, and, in the absence of means of repair, soon becomes worse than useless. Complex arrangements are not employed where the end can be gained by simpler means. The life of most perfect insects is of very limited duration—the wasp is no exception to this general law—and is for a very definite object. So no more stores are laid in than are enough to carry the ship into port after her short voyage. There are no spare spars, no materials for executing repairs; indeed, an injury to a perfect insect is irreparable. Everything is made on the simplest plan and in the way least likely to get out of repair. The cornea—in the instance of the compound eye now before us—is made to do the duty of the lens also. The moveable iris, with its muscles and blood-vessels, as seen in our own eyes, is replaced

in the compound eye by a layer of black paint, as fixed as the stops in our microscopes. All is arranged at once on the best plan for the particular object in view; the insect can do what it is intended to do perfectly, and nothing else. All is as strong as cast-iron, so to say, but if anything break, like cast-iron, it cannot be mended.

For a thing of such a size, this plan, and for another size, another plan of construction is preferable. This we learn by the common rules of Mechanics. But, beyond this mechanism which we can copy, there is something which we cannot copy, nor quite understand, in the adaptation of the functions as well as the structural arrangements of the parts to the requirements of the animal. In the higher animals, still keeping to the instance before us, various mechanical contrivances are provided, to moderate the admission of light into the eye, and to adjust the focus of sight. In the insect we find none, or next to none, of these; yet, for all that we can see, they are just as necessary for an insect as for a bird. A wasp, for the speed of its flight, needs a range of vision as long and as wide as that of many birds. Again, its habits of working alternately in bright sunshine and in almost absolute darkness would seem to require as perfect an adaptation of its eyes to these alternatives as the nocturnal beasts of prey possess. But the adjustment of the focus and the mode of the adaptation equally baffle us, and we must be content to leave the question as to how these are effected unanswered.

The form and outline of the compound eyes in the wasp tribe, both solitary and social, should be noticed. They are separated into two limbs, so

called, by a deep notch on the inner side, just at the point where the scape of the antennæ lies in front of them. In some species of our Vespæ the notch in the dark eyes is brought out more plainly by the integuments here having a bright yellow colour, and in them, all the lower limb of the eye is at least edged with yellow. In the Solitary group, as the movements of the head are limited by the front of the thorax being full and square, to make up for this restriction their compound eyes are proportionately larger and more prominent than in the Social group, where the free movements of the head on the rounded thorax give a wide range of vision. There is no notable difference in the extent of the compound eyes in the sexes of wasps, but in the male of the honey-bee they are much larger than in the worker, and meet across the vertex of the head, as in some of the common flies.

Between the eyes, separated at their roots by the width of the corona, the antennæ take their origin. They are of the simplest possible form, like thick black hairs, hard and polished, and beaded all the way down. The number of these beads or joints, and their relative size, are points of technical importance. A long joint, which has already been referred to under the name of the scape, begins the series. Then comes a very short one, on which the antenna generally turns at an angle, is geniculated, as it is called. Ten more joints go to make up the flagellum or flail; the first somewhat longer than the rest. In the males there are eleven joints here, thirteen in all. This odd joint is simple, like the

rest, in the Social, but hooked in the Solitary group, and furnishes a most useful aid in classification. The front of the scape is yellow, as already noticed, in all the sexes of the tree-wasps, and in the males of the ground-wasps. It is important to recollect this, as well as the number of the joints, and the fact of the terminal joint being hooked in the males of the Solitary group.

A longitudinal section of the antennæ of the hornet discloses a series of chambers jointed together. The central space, according to Mr. Newport's description of the antennæ of *Ichneumon Atropos*, is occupied by a nervous filament, and copiously supplied with a limpid fluid. On either side of this, in the hornet, is a trachea, contracted at the joints, but swelling out in the interspaces, and giving origin to little air tubes which ramify over the interior of the horny covering. This covering is composed of fibres, forcibly recalling the appearance and arrangement of the enamel fibres of the teeth, radiating from the long axis of the antenna, presenting a rough surface externally. A longitudinal section of one of these antennæ, under polarized light, is an object of exceeding beauty.

Popularly the antennæ are known as the insect's feelers, and certainly one of their uses is to examine by touch anything presented to them. If we confine one of the Orthoptera, a cricket or grasshopper, for instance, with its fine, long, antennæ, in a box with a glass lid, we may easily satisfy ourselves on this point. But they are not the only organs of touch, as the palpi of the mouth share this sense with them; nor are their functions limited to the

exercise of this faculty. Doubtless the plumes of the gnat, the leaves of the cockchafer, the beaded filaments of the wasp, and the other countless forms which the antennæ assume in different tribes, have a direct relation to the several habits of the insects which wear them. But, besides all special adaptations, the proper function of the antennæ seems to be that of an instrument of communication in the social tribes, and of an organ of hearing in insects generally.*

The first of these functions has been assigned to these organs by the common consent of all naturalists. What form the communication takes to become intelligible cannot be known, but by means of these little jointed threads, a kind of freemasonry is maintained among the members of a colony, and such a fact as the presence of the queen is transmitted, even through a grating, with as much accuracy as along the telegraphic wires. Ants and bees seem to converse, and call for assistance, by contact of their antennæ, just as the deaf and dumb do by motion or contact of their hands. Wasps, which are less sociable among themselves, and work singly, are perhaps less demonstrative in this way than bees and ants, and exhibit less of this interchange of feelings. But they have means of telling one another what is going on, and very accurately, too, if the curious observation that a wasps'-nest may be attacked with impunity if the outsiders be kept from

* See Newport, On the Use of the Antennæ of Insects, 'Transactions of the Entomological Society of London,' Vol. II, p. 229. 1837—40.

communicating with the wasps inside the nest be correct.

With reference to the sense of hearing, one reason for regarding the antennæ as equivalent to the ears of the higher animals is that no other organ has been discovered in insects to which this faculty can be assigned, though it is quite certain, from observation, that insects do not only hear, but make noises with the intention of being heard. As we rise in the scale of Creation, where distinct organs of hearing do appear, they are found close to, and supplied by the same nerves as the antennæ. The hard horny covering of these organs makes them, in the wasp at least, ill adapted for instruments of touch, but in that measure fitted to receive and transmit vibrations of sound.* And in their general structure we may perceive a close analogy to the loose chain of ear-bones of mammalia, or to the bony needle which in birds performs the same office of transmitting vibrations from the membrana tympani to the auditory nerve.

Those who have tried most experiments are most alive to the sources of fallacy which vitiate the conclusions from them. We know, from the effects of accident or disease in ourselves, how very small a portion of an organ, how seemingly imperfect an ear, may suffice to carry on its duties. And we know how very little is to be based on the actions of a creature frightened and excited by such mutilation as would be necessary to destroy completely any organ of special sense with all its means of external

* See on this subject Rymer Jones, 'General Outline of the Animal Kingdom,' 8vo, 1841, p. 275.

communication. Experiments on the perception of sound are singularly open to such objections, and I will not build on any conclusions from them. The proof from comparative anatomy, and from the fact that an instrument shaped in the form of the wasp's antennæ is a very good means of collecting and conveying sound to the point where it can be appreciated, seems to me the best proof we are likely to get that the antennæ of wasps are really their ears.

The various forms which the corona, the little yellow patch which lies between the origin of the antennæ, presents have been already fully described in pointing out the distinctions between the several species. The external figure of the clypeus is less varied. This is the broad yellow shield on which wasps wear the characteristic devices of the different species. It is of an elliptic form above, with occasionally a notch in the middle line. As the sides diverge they come into contact with the lower limb of the compound eyes. The outline is completed below by two straight lines converging to a point, more or less truncated in different species, corresponding to the commissure of the mandibles. The clypeus gives form and width to the face, and protects the soft parts of the mouth which lie immediately behind and beneath it.

The structure of the mouth has been made the basis of one system of classification of insects. But, as these parts are not as open to common observation as the wings, the system of Fabricius has been superseded by that of Linnæus, which supplies much more

readily available distinctions. Still, these parts of the mouth will repay a careful study, as well on account of their physiological importance, as for the sake of the unerring differential characters which scientific examination finds in them.

The mouth of the Wasp, and of the Vespæ in particular, furnishes a very good illustration of the mandibulate or masticating form of the organ, where no single part is enlarged or diminished very disproportionately to the rest. It is very difficult to make a symmetrical microscopic preparation of the whole oral apparatus, as the parts are of such different degrees of thickness and hardness, and require such different modes of treatment to show them to the best advantage. But they may be seen in detail, and their description may be followed with the greatest ease, if they are merely loosely spread out on a slide with a little glycerine.

The mandibulate form of mouth, as displayed in our wasps, is made up of the following parts. There is an upper lip, the labrum, which is a simple scale having a vertical plane of movement and a lower lip, the labium, which has a corresponding direction of movement, but is of a more complex structure.



Fig. 1.—Diagram of the several parts of the mouth of the wasp.

- a*, labium with the four-lobed tongue and the two labial palpi.
- b*, maxilla of one side, the basilar portions bearing at one end the cardo, at the other the hairy galea and the maxillary palpus.
- c*, labrum.
- d*, mandible of one side.

There are a pair of mandibles which meet in the middle line working transversely, and which are said to represent the upper jaw. And, lastly, there are a pair of maxillæ, which are said to represent the lower jaw, which have a free movement in every direction, and lie concealed behind the mandibles. These will all require a separate examination.

The larger size of the hornet renders her the most convenient subject for examination; and for the study of the hard horny parts perhaps a dried specimen is the best. If we carefully examine the truncated angle of the clypeus on its lower edge, we shall find, closely connected to the back of it, a small crescentic horny flap, having a leaf-like projection from its centre. This is the labrum, or upper lip, which lies immediately behind the line in which the mandibles meet, and closes the cavity of the mouth above. It is much larger and more distinct externally in the honey-bee than in the wasp, but it still retains the character of a simple membranous flap, armed perhaps with bristles, but with no secondary organs such as we find on the lower lip.

The mandibles are at once to be recognized, occupying the lower part of the face beneath the clypeus. In the Solitary group they are long, and run out into a beak as they meet each other in the middle line; or they overlap like the mandibles of the crossbill. This form and arrangement is almost peculiar to the Solitary group, and differs widely from that found in our Wasps, which have short, strong mandibles, ending, not in a point, but in a serrated edge, resembling rather a half closed paw, or the claw of a dentist's key, than the bill of a bird.

The mandibles are moved by a very powerful mass of muscle which lies just behind the compound eye on either side, occupying the greater part of the side of the head. If we break this part of the head open the dried muscle falls out. It is a mass of fibres, converging from the inside of the rim which surrounds the face, to a tendon which is inserted into the mandible at its articular extremity. The bulk of the muscle offers a sufficient explanation of the amount of work that a hornet can get through.

The articular surfaces are broad, and set in such a direction as that the mandibles shall move in the plane of the face. In the hornet there is a little wider interspace between this joint and the lower part of the compound eye, than is found in the smaller wasps. As a rule, the mandibles of the Solitary group come closer up to the eye than those of the Social, but this character is not very distinct in the *Vespæ*. The main strength of the mandible lies in the long claw which forms the lower edge, coming direct from the joint to meet its fellow, tipped with two strong black teeth. In form, this is very like that which we see finishing off the little round black faces of the *Odyneri* beneath, and which constitutes the whole mandible of this species. But as the hornet not only cuts and carries, but also moulds, a triangular piece is added for this purpose, shaped like a woodman's axe, but with a serrated edge. It is this triangular piece which gives such length to the face of the hornet, as to that of the smaller social wasps, and which, indeed, is the chief part of the mandible that shows in front.

If we turn the little fragment round, so as to show

the other face, we shall find it hollowed out on the inside, swelling up towards the articular extremity, but thinned off to the cutting edge. And it must be indeed a cutting edge when worked by its powerful muscles. For, besides the points which show on the outside, there is another set of cusps within, separated from the former by a channel like that which runs between the teeth of a double toothed pocket-saw, or, coming nearer home, between the outer and inner row of the cusps of our own upper molar teeth. Wasps have no gizzard, no cutting or grinding instrument such as crickets and cockroaches possess, placed further in to break up any refractory morsels of food. Whatever is to be done in this way must be done here by the mandibles. But wasps live mostly on pulpy matter or juices, they do not triturate hard substances into a digestible mass, they only break them down to get at the nutritive material which these contain. So their jaws are fitted with teeth rather for cutting, tearing, and sawing, than for grinding, like a dog's rather than a horse's; they are for collecting materials rather than for masticating food, and are shaped accordingly.

We have yet to examine the most complex portion of the mouth, the labium and maxillæ. As these parts supply very important specific distinctions, it is useful to be able to remove them for examination without disfiguring the specimen. This can be readily effected, in a recent or a moistened specimen, by gentle manipulation with a needle behind the mandibles. With care, a mass can be removed, in which we shall find the labium and maxillæ entire and in their natural connection. And, in the absence of the

hard unyielding mandibles, these may be spread out very satisfactorily for microscopic demonstration, under a glass cover with a little fluid.

Under gentle, gradual pressure the mass divides into three distinct parts, one in the middle line, and two others, arranged symmetrically, one on either side. We shall find, on a mere general and superficial examination, quite enough for our present purpose, and indeed, our examination will be facilitated by mounting the object in glycerine rather than in Canada balsam; as the multiplicity of the details is not so perplexing in the less transparent medium. The closer we look the more there is to be seen; more than any books or plates will explain.

Limiting ourselves, however, here to tracing the main outlines. The central piece is usually called the labium or lower lip, though sometimes the application of this term is limited to the thin membrane which others call the tongue or ligula. Here, applying the term labium to the whole central portion, we may adopt the term of mentum or chin for the base to which its several constituent parts are connected. Tracing these from behind forwards, the mentum appears on the slide as a dark membrane lying in folds, shaped like a leaf. It is rounded at the posterior, but cut off square, and slightly notched, or stepped, on either side, at the anterior extremity. On these steps the labial palpi are fitted. These are a pair of feelers, jointed like the antennæ; only they are very much smaller than them in every way, and are clothed with fine hairs. The successive joints diminish regularly in length from the first to the free end. They are four in number; never less in any of

the social wasps, though some of the solitary wasps have only three joints. They stretch out forwards, and between them lies the ligula or tongue, which is attached to the square end of the mentum. This tongue is a clear white, transparent structure, covered with fine hairs, the arrangement of which gives the appearance of delicate transverse markings at the tip. Here it is split into four lobes or points, each tipped with a round horny spot, which has been sometimes called a gland. The two central lobes are broader, and are separated by a comparatively shallow notch; the lateral lobes are longer and narrower; the cleft, which divides them from the body of the tongue, being much deeper. These last are called the laciniae, that is to say, the outer hem or fringe of the organ.

It will assist us in the examination of these very complicated structures to follow, as much as possible, their natural divisions. And as the labium had a mentum, a ligula, and a pair of palpi, so the structure of the maxillæ admits of, and will be made more intelligible by, a similar sub-division. As the specimen lies in glycerine under the microscope we can readily distinguish two long dark horny limbs converging to a point. The labium lies between these, and we can trace the delicate membrane by which it is connected to them. They are the basilar portion of the maxillæ, that is to say, the base to which the several portions are attached, and the point, consequently, from which it will be most convenient to commence their description. The maxillæ, as already observed, are conventionally supposed to represent the lower jaws of the vertebrate class.

To the anterior extremity of either basilar portion

the maxillary palpi are connected. These are, generally, similar to the labial palpi, but have two more, namely six, joints. This is the typical number for the Vespæ; some of the Vespidae have only five, and some of the Eumenidæ no more than three joints. The successive joints diminish regularly in size until the last which, though slighter, is somewhat longer than those immediately preceding it.

Outside the palpus, springing like it from the anterior extremity of the basilar portion, but from a much broader base, is the galea. It is most aptly so called, from its crest-like form, and the long hairs with which it bristles. The student of human osteology may well envy the entomologists the happier comparisons by which the details of insect anatomy have been illustrated, here as elsewhere.

The inner edge of the basilar portion is clear and well defined, lying as we have seen, parallel to the mentum of the labium. The outer edge is more rough and ragged, especially at the root of the galea. But as we trace it backwards it is more sharply defined, till the limb terminates in a rounded extremity to which another shorter horny piece is articulated. This little fragment is called the cardo or hinge, on which the whole oral apparatus turns. Diverging from its fellow as it passes backwards it offers a firm point of attachment to the muscles and membranes which go to constitute the intricate mechanism of a wasp's mouth.

I do not doubt that the small portion of the anatomy of this part which it is necessary to understand and to remember for practical purposes, may be made

quite intelligible and fixed in the memory with a very little pains. Wasps and microscopes are so very common, and so easily accessible, that I have introduced the diagram on a preceding page rather to point out which are the parts to the student than to attempt to show what he might so readily see for himself in the book of Nature. On the other hand, I must add, with as little doubt, I am sorry to think, that this description, after all my endeavours to simplify and shorten it, will have appeared dry and tedious. I must acknowledge that all these details are somewhat repulsive ; but, if they are to be mastered at all, they require close attention. And the labour will be amply repaid ; for on the form of the parts of the mouth which have just been reviewed, and especially on the numbers of the sub-divisions, wherever this mode of comparison is applicable, specific distinctions are based which are not the less valuable because they require a microscope to display them.

It certainly gives a higher interest to such details, and assists both to understand and retain them in the memory, to transfer to the parts of insects the terms of the anatomy of the higher animals. But it is only with great reservation that we can venture thus to apply these terms. Many entomologists, as has already been said, doubt whether the horny covering of insects be not more strictly analogous to our outer skin than to our internal skeleton. And we should bear the possibility of the reasonable existence of a doubt on such a fundamental point in mind when we go beyond this and attempt to trace any close analogy in detail between the parts of the

mouth of insects and Mammalia. The figure of speech may be very convenient, but the analogy is very fanciful, which finds our upper and lower lips severally reproduced in parts so dissimilar from each other as the horny labrum and the complex labium, or compares our upper and lower jaws respectively to the horny mandibles and the complex maxillæ. They may answer similar purposes, but the things themselves are wholly different.

But if we limit the range of our fancy within more legitimate boundaries, and content ourselves with tracing the real analogy which exists between the component parts of the mouth in different families of insects respectively, we shall still find enough to do. Dissimilar as the various parts of the mouths of different insects may appear at first sight, both in form and function, nevertheless, their essential identity has been traced in the most satisfactory manner. To take a few familiar instances. In some of the Eumenidæ the mandibles cross each other, or stretch out into a beak, thus forming a pair of forceps adapted to hold anything. In the Vespæ they are shortened into a saw fitted with a limb for flattening the paper. In the male stag-beetle they appear as horns of as full proportions as those of the quadruped from whence they are named. In the flea these are the cutting lancets which make holes in our skins, and in the butterfly they are almost obsolete.

Or take the maxillæ. In the flea these are transformed, like the mandibles, into lancets. But in the butterfly and moth they undergo quite another change of form. They are extended to the length of one or two, or more inches, while the edges are turned

in, so as to meet the corresponding member and form a long tube, the proboscis as it is called, with which the *Lepidoptera* suck honey from flowers. The maxillary palpi do not share in this singular development, they are almost obsolete. But the labial pair, which we have learned to regard in the wasp as organs of feeling and perhaps of taste, are transformed into a sheath for the long delicate proboscis which is coiled away between them.

Only one more instance of the wonderful changes and combinations of these variable parts; and this from the honey-bee. Here the proboscis is not formed, as in the butterfly, from the maxilla, but from the ligula or tongue. We have seen this in the wasp as a squarish membranous expansion, indented at the extremity. In the honey-bee the central part is protracted into a long strap or stalk, which is clothed with fine hairs, and tipped with a button at the end. It is not tubular, as in the butterfly, for the bee does not extract the honey by suction, but by repeated immersion of the tongue in the fluid. One might have thought that for the same simple purpose, namely that of collecting honey from flowers, the same organ would have been employed in these two classes of insects. But the fertility of invention is nowhere so lavishly displayed as in insects; and a close examination shows the proboscis of the honey-bee to differ from that of the butterfly in its anatomical structure, in its development, and in the mode of its application.

There is as little doubt that wasps smell as that they taste, or see, or hear: many of their movements

are guided by this faculty; and the only question is where the sense of smell resides. As the odorous particles are conveyed by the air to the organ of smell in air-breathing animals, the respiratory movements, which draw the air, have an obvious mechanical connection with the exercise of this faculty. But the connection of the sense of smell with the sense and organ of taste is certainly much closer than with the lungs. All the analogies of the higher animals, all that we know of ourselves, all that experiments seem to show, point to the mouth, rather than the general tracheal system, as being the seat of the sense of smell in insects. And experimental observation rather favours this conclusion. Bees were repelled by turpentine placed before their mouth, but not by the same being placed near their spiracles.* Smelling with the lungs, which must be very like smelling with the tracheæ—if insects really can do this at all—is a process with which many of us may have been painfully familiar. Every anatomist knows what it is to taste a smell, when the blood has been saturated with the poisonous air of the dissecting room, and how different this is from smelling in the ordinary way by the nose. But insect smell must be something much more acute than this, and of much more definite application. The difficulty is to understand how so small a surface as an insect's mouth offers, with a limited afflux of odorous particles, can be so sensitive an instrument as by its capacities we know the organ of an insect's smell to be.†

* Van Der Hoeven, 'Handbook of Zoology,' Vol. I, p. 281.

† 'Burmeister Entomology. Trans.,' p. 485, dismissing Kirby and

It is the same difficulty as appears with regard to the eyes of insects; we cannot understand how so small a nose can smell, any more than how such imperfect eyes can see so acutely. There are more things in Insect Physiology than can be explained by the physiology of the higher animals. Yet we must not ignore those physiological principles. Latreille* assigned the faculty of smell to the antennæ. But all analogy is against this conclusion. We may admit that the rule which requires a well-developed nose for a strong scent, and a well-developed brain for a strong intellect, and which expresses the points of a horse in the terms of anatomy, is not altogether applicable to insects; though we cannot tell exactly why. But the physical objections to his theory are very strong. Moisture seems an indispensable requisite for a part which is to appreciate odorous particles, and that is singularly wanting on the receiving surface of the antennæ.

Spence's supposition that there is a peculiar organ of smell inside the mouth, assigns the faculty, not to the mucous membrane lining the rest of the mouth, but to that lining the tracheæ.

* Newport, 'On the Antennæ,' *sup. cit.* p. 231.

CHAPTER IV.

ANATOMY AND PHYSIOLOGY.

THORAX. EXTERNAL SKELETON. CONTENTS. APPENDAGES :—LEGS,
WINGS. MECHANISM OF FLIGHT.

THE thorax of insects presents to the entomologist a problem very like that which comparative anatomists have found in the vertebrate skull. Both these parts are composed of elements which appear in a simpler form in other parts of the body, in the rings of the abdomen and the spinal vertebræ respectively. The various forms, however, which the corresponding parts assume are not always easily referred to their original types. Their identification is often, indeed, a work of great difficulty. Excessive development in one, almost complete obsolescence in another, and fusion of distinct elements into a compact form in a third, produce forms in which none but the most skilled anatomists can clearly trace the homologies of insect or vertebrate structure.

Entomologists have the more difficult task in this analysis, on account of the minuteness of the subject of their examination, and of the want of much of that help which comparative anatomists obtain from observing the gradual development of

the different bones. And not a little additional difficulty has been thrown over the subject by confusion in the nomenclature of the various parts of the thorax. This difficulty pervades even the most elementary descriptions, the same word being often used in a different sense by different writers; and I can scarcely expect to have escaped altogether from this source of confusion, although it is only with the chief divisions, about which nearly all are agreed, that we are here concerned.

Fig. 2.—Diagram of the divisions of the thorax traced on its dorsal aspect.

- a*, prothorax, 3 scutellum.
b, mesothorax, 2 scutum.
 " 3 scutellum.
c, metathorax, 2 scutum.
 " 3 scutellum.

The darkest lines indicate the divisions of the segments. The next shade denotes the subdivisions. The finest lines mark the boundaries of the yellow patches which are seen on the smaller wasps.



The first larval segment, as we have already seen, is absorbed in the formation of the head of the perfect insect. The thorax accounts for the three next segments, namely the second, third, and fourth, which constitute severally the *pro*-, *meso*-, and *meta*-thorax. Each of these segments is subdivided into four rings more or less distinct in different species, to which the names of *præ*-scutum and scutum, scutellum and post-scutellum have been given. And each of these has again been divided into a dorsal and a sternal, that is to say, as the insect stands on its legs, an upper, and a lower or lateral portion. Altogether, on the simplest mode of arrangement, there are twenty-four distinct pieces into which the insect

thorax is divided; and some anatomists count many more. The details of all these parts, particularly as displayed in the thorax of the Hymenoptera, have a special interest for entomologists. Our present field of observation, however, is much more limited, being almost exclusively confined to the dorsal surface, and to this, too, rather in a general than in a purely anatomical point of view. Indeed, the appendages of the thorax, the legs and wings, claim more of our attention than the skeleton.

The prothorax is the first division of the thorax, counting from before backwards. In the Hymenoptera this forms one compact piece, in which the lines of division of the component parts are not very easily distinguishable. The posterior boundary, however, is marked clearly enough on the dorsal surface, by two yellow lines which run backwards, diverging from behind the neck to the scale covering the root of the forewings. These yellow lines are the only distinctive marks which this division of the thorax displays in our British Vespæ, though in some foreign genera, especially in *Polistes*, the whole of the dorsal portion of the prothorax is highly coloured. Both in the Social and Solitary group the prothorax is prolonged backwards to an unusual extent, apparently to give additional space within it for the front attachment of the depressor muscles of the wings. The portion of the prothorax which appears on the back represents the scutellum. The morphological nature of the loose ring or collar which surrounds the neck has been the subject of much discussion, but it is now pretty generally agreed that it represents the sternal portion of the thorax, and should,

strictly speaking, be called the prosternum. It carries the front pair of legs, which are the only appendages of this division of the thorax.

We must sacrifice many specimens to gain any clear idea of the arrangement of these parts. The lines of division between the different segments are more easily traced on the inner than on the outer surface, and in a dried than in a recent specimen. If we break a dried thorax carefully to pieces, we find the edges turned in to fit against each other along these lines of division. The first and last rings of each segment, in fact the præ-scutum and the post-scutellum, are, as a rule, thus turned in and do not appear at all on the surface. By the apposition of these flanges the connection is strengthened, and a ridge is formed for the attachment of muscles on the inner surface.

The meso-thorax is chiefly represented by its scutum or second, as the pro-thorax is by its scutellum or third, component ring. The peculiar conformation of the back of the thorax of wasps is due to the development of the meso-scutum into a broad convex surface. It is black in the smaller wasps but variegated in the hornet. Behind it lies the scutellum, which is a transverse band, brown in the hornet, but in the wasps black, with the exception of a semicircular yellow spot at each end.

Not to map out the thorax with tedious minuteness, I would only indicate the chief divisions on its lateral aspect. As the divisions of the back are expressed by variations of the word *scutum*, so the sides have had the word *sternum* appropriated to them in nearly the same way: there is a *pro-, meso-*,

and *meta*-sternum. The wings mark by their insertion the division between the sternal and scutal regions. The prosternum we have already seen. The sternal portion of the meso-thorax, called, according to this simple nomenclature, the meso-sternum, is represented by a large convex plate, marked in the smaller wasps by a bright yellow triangular spot. The lower end of this plate seems to slope backwards into a point which bears the middle pair of legs, while the fore-wings, with their little yellow wing cover, or tegula, are attached at the upper part. Just below and rather in front of the wing cover, in the line which separates the pro-thorax from the meso-thorax, the first part of thoracic spiracles open by a curvi-linear orifice which is not readily distinguishable without a little practice, notwithstanding its large size.

The size and general development of each division of the thorax bears a close relation to the size of the appendages which it supports. In wasps and butterflies the front pair of wings is the largest; so the meso-thorax is more developed than the meta-thorax which bears the hind wings. In beetles, which carry their wings on the meta-thorax, and the wing-covers only, which we must not confuse with the little wing-covers of the wasp, on the meso-thorax, these proportions are reversed.

The meta-thorax has the same fourfold division, and the same general arrangement of its elementary parts as the preceding segments have. The præscutum is turned in; and the scutum, as in the meso-thorax, bears a pair of wings. But, instead of presenting a broad convex surface, it forms a transverse

band, narrowed to a point at either end, and drawn out in the middle into a cusp, which nearly divides the scutellum behind it into two. This cusp marks externally the position of a longitudinal ridge which affords attachment to the great depressor muscles of the wings within. The scutellum again has a peculiar form, something like that of that most useful object of comparison, the ace of hearts. There is not much of this portion of the meta-thorax to be seen on the back, but on either side a broad round surface appears, on which the orifice of the second thoracic spiracle is a conspicuous object. This arrangement is characteristic of the Hymenoptera. In all other orders of insects the second pair of thoracic spiracles are placed, like the first, in the division between two segments, between the meso- and meta-thorax ; in the Hymenoptera they are formed in the meta-thorax itself. The post-scutellum, in the form of a narrow ring notched for the passage of the tendon of the suspensory muscle of the abdomen, closes the thorax behind.

The meta-sternum, as the whole thorax narrows, is smaller than the meso-sternum, but, like it, slopes off behind to a point which bears the hind legs. The hind wings are attached over its upper extremity.*

The study of the skeleton is only the opening of

* The article *Insecta*, in the *Natural History* division of the 'English Cyclopædia,' may be consulted with advantage on the subject of the *Anatomy of Insects*, by those who have not the opportunity or the leisure to study the more elaborate essay in the 'Cyclopædia of *Anatomy and Physiology*.' The diagrams of the thorax of the hornet are beautifully clear.

further inquiries. For the divisions of the framework have a definite relation to the internal arrangement of parts, and particularly to the insertion of the numerous muscles which are contained within the thorax, and, indeed, almost entirely fill its cavity. The muscular structure of insects differs from that of the higher animals in having no connective tissue placed between the different bundles of fibres of which the several muscles are composed. This circumstance gives great facilities for its microscopical examination, for, under pressure, the muscle breaks down at once into its constituent fibres, without any of that teasing which is so injurious to the structural arrangements of the muscles of the Vertebrata. Nor is there any connective tissue to fill up the spare room between the different muscles; if indeed there be any spare room at all in insects. Each muscular fibre, however, has its own investing membrane, or sarcolemma, which can be traced, at any point where the fibre has been broken or twisted, as distinctly as in some fishes whose muscles are familiarly used to display the sarcolemma. Again, the important distinction between the voluntary muscles which are subservient to the will, and the organic or involuntary muscles, whose action is reflex and independent of the will, apparently follows the same rule in insects as in the higher animals. To take the instance before us; the little muscles which move the head and legs of the wasp, the bulky muscles contained in the side of the head, which move the mandibles, and those which protrude the sting are all voluntary, so also—I am pained for the reputation of my favourites to say it—are those which encircle the poison-bag and inject

the venom into the wound. All these, to mention no more, are marked by distinct transverse striæ—the anatomical character of voluntary muscles throughout the animal kingdom. But the bulky muscles which move the wings in flight are of a different kind: the fibres of which they are made up are regular and have each their separate sarcolemma, but they display no distinct transverse striæ. Some kind of transverse marking is to be observed, arising, apparently, from the coincidence of the divisions of the granules of which the different filaments are made up, and these lines are three or four times as closely set as the striæ on the voluntary muscles. But these transverse markings are neither regular nor constant, and the difference between the two orders of fibres catches the eye at once. We find fibres of this order in the vertebrate uterus, or bladder, or bowels. Speaking generally, wherever a frequent or long-continued repetition of similar movements is required, this function is made independent of the will, so that it may go on without interruption from weariness, or other causes which affect the will; and its performance is committed to organic or involuntary muscles. Such are the muscles of flight in insects.

Nothing is omitted in the adaptation of the muscles of flight in insects to their work. Their bulk at once bespeaks their strength. By their organic structure they are fitted for movements, which are unchanged except in the rapidity of the vibrations, and to labour, which is unremitting hour after hour. They are protected from the sense of weariness which affects voluntary muscles, and they are supplied most freely

with all that muscles in action require for their constant renewal. The air-vessels by which they are traversed are much more numerous than the capillary blood vessels which ramify among our muscles; each fibre is crossed or encircled by little tufts of tracheæ, springing at right angles from long straight tubes which run parallel to the direction of the muscle.

Wasps, on account of the small size and the hardness of the integument of the thorax, are ill-adapted to display the exact mode of arrangement of the muscular system of this part: this must be studied on larger insects encased in more yielding walls. So I will not do more here than indicate the general disposition of the muscles of the thorax. These may conveniently be divided into two classes, in accordance with the distinctions between voluntary and involuntary muscles which have just been pointed out. First, closely nestled together in the corners between the ridges which project on the inside, and crowded into the wall-spaces along the lower and anterior surface of the thorax, are many little muscles which move the head and legs. These are of a whiter colour than the mass which occupies the centre of the thorax, and their microscopic structure shows them to be voluntary muscles. Other muscles of the same order run down into the limbs to perform the few simple movements of which these parts are capable. Besides these little slips, there are two, or rather two pair, of large muscles which cross the cavity of the thorax in opposite directions, nearly at right angles to each other. If we break the dried thorax of a wasp these large masses fall out, the empty spaces

showing how considerable a portion of its cavity they occupied. But we may learn more of their form and connections by examining them in the recent state. Thus displayed they appear of a reddish yellow colour, they are freely supplied with tracheæ, and their fibres have the microscopic characters of involuntary muscle. They have no lateral attachments, they simply cross the thorax, one end being attached to the wall on one side, and the other end to the opposite side. These are the muscles of flight. No more simple arrangement for driving the wings could possibly be conceived, not even in insect mechanism. Thus, one pair start from the inside of the scutellum of the prothorax, and, descending as they pass backwards, are inserted into the scutum of the metathorax, whose long cusp seems adapted to receive them. By their contraction the first and last segments of the thorax are approximated, and the intermediate segment, with which they have no connection, is thrown up in an arch, and the wings are simultaneously depressed. The other pair lie outside these, and cross their direction. They start from the outer end of the scutellum of the meso-thorax, and passing downwards and forwards, are attached on the firm front edge of the thorax; the scutellum of the pro-thorax again furnishing the point of resistance. The arch of the back, which was raised by the action of the other pair, is depressed by these, and simultaneously the wings are elevated. From their action on the wings, though they are not directly connected with them, these two pair of muscles take their names, as the elevators and depressors of the wings respectively.

This mode of arrangement of the muscles of flight obtains generally through all the families of insects. A singular exception is found in the dragon-fly,* where the muscles are not inserted into the walls of the thorax, but pass directly to the root of the wings. The muscles of flight are much more elaborately developed in this insect than in the wasp, and movements which are intrusted in the wasp to self-acting mechanism are performed in the dragon-fly by special muscles. To make room for all these, they are tapered off and fitted to tendons at one end, just like the muscles of the higher animals. We may readily trace their arrangement in a recent specimen, and observe the mode of attachment of the muscular fibres to the black cups into which the tendons expand to receive them. But the specimen must be quite fresh; for the least putrefaction loosens all their attachments, and the muscular bands become undistinguishable from each other.

The elevators and depressors of the wings are the mainspring, so to say, and execute the effective movements of the wasp's flight. But their action is supplemented in all its minor details by other smaller muscles, strong enough to guide, though not to drive, the wings, able to fold or expand them, to lock or unlock them at will, and to draw them at each moment into the right position for the stronger muscles to act upon them.

Deferring the full consideration of the problem of

* See Bennett, On the Anatomy of the Thorax in Insects, and its Functions during Flight, 'Zoological Journal,' Vol. II, p. 391, referring to Chabrier, sur le Vol des Insectes, 'Memoires du Mus. d'Hist. Naturelle.'

flight to a later period, when it may be studied in connection with the structure of the wings, it remains here to notice briefly another function of the muscles of flight. For the full sustained action of these, as of all other muscles, the freest possible access of air or of aërated blood is necessary. Accordingly, in wasps, as in all other insects, the movements of flight and those by which thoracic respiration is carried on are co-ordinated. The air is pumped in and out as the wings rise and fall, and the insect breathes and flies simultaneously by the action of the same muscles. By this means the supply of air is exactly proportioned to the demand, and respiration is carried on most vigorously during flight. When the wings no longer vibrate thoracic respiration simultaneously flags or ceases.

The chief part of the space of the thorax is given up to the muscles of flight. But, besides these and the smaller voluntary muscles which move the legs, there are other organs which, without attention being particularly directed to them, might readily be overlooked.

The salivary glands form a mass of considerable size in the front of the thorax, lying on either side of the oesophagus, just beneath the horny integument. They are obtained most easily for examination by a horizontal section of the thorax just above the level of the oesophagus. The general arrangement may be made out piecemeal without any great difficulty. But, after many trials, I have never succeeded in displaying the pair of glands perfect, as they are described, with the duct from either side carrying their

secretions into the oesophagus. In their structure the salivary glands differ from most other glands of the wasp, and indeed of all other insects. They are not tubular, but composed of separate gland-cells, arranged on the arborescent plan of many glands of the higher animals. These gland-cells are discs of various sizes, about a ninth of a line in diameter, on an average, in the hornet. They are clear and transparent when the insect has been kept long without food and in confinement; and then they display one or more nuclei. But, in a freshly caught healthy queen wasp I have sometimes seen them opaque and finely granular. They are each inclosed in a membranous bag, which contracts into a duct or stalk on which they hang, and which serves to convey their secretion to the common duct. The whole gland on either side might be compared to a bunch of grapes, or, better perhaps, of raisins; only the ducts are rather longer in proportion to the size of the gland-cells than the grape-stalks. The larger ducts are distinguished by their pale reddish-yellow colour, by the fine, soft, spiral fibre which surrounds them, and by the great thickness of their outer coat which is very obvious in the larger ducts. Even when they contain air, which they often do in small quantities, their colour and the thickness of their walls will distinguish them at once from the air-tubes proper with their dark sharp outlines. The smallest ducts have no spiral fibre, and they need careful adjustment of the light to display them satisfactorily, or indeed to shew them at all.

1 The salivary glands are connected in name and position only with the digestive system. They have

really nothing to do with digestion ; their proper function is to secrete silk or mucus, to form the cocoons of the pupæ, or the nests of the perfect insects. The nature of the secretion differs not only in different insects, as we might have expected, but in the same insect at different periods of life. To take a few familiar instances. The frothy fluid with which the honey-bee kneads her wax plates till she has formed them into a paste of a proper consistency is derived from the salivary glands. So is the well known substance of which silk-worms make their cocoons. Probably the caddis-worm derives the hydraulic-cement with which she fastens her building materials together, from the same source. The poison which biting insects—biting in the domestic, not the entomological sense—inject into the wound, is also a secretion of the salivary glands.

The spider takes rank next to the various species of silk-worms as a silk-manufacturer. But they do not secrete it from their salivary glands, which have quite a different function. The spider's spinneret opens on the outside of the abdomen by numerous orifices, and the separate strands do not coalesce into one thread till they reach the open air, instead of within the ducts of the gland. This makes the thread of the spider appear of a more complex and elaborate structure than the silk-worm's, but it is not necessarily so. It would seem to hold a middle place between that of the silk-worm and the wasp in the rapidity with which it takes a solid form. The thread issues ready formed from the mouth of the silkworm. In the spider's thread the drying process, however instantaneous, requires the access of the

air. In the wasp this cohesion is further delayed; the fluid secretion requires a longer exposure to make it harden; the separate threads meanwhile melting into each other, so as to form a membrane rather than a web.

From the earliest period, as we shall see further on, the secretion of the salivary glands is more free in the wasp than in the honey-bee, their cocoon is thicker and stronger in all its details, increasingly so to the cap, the crown of larval labours. In the honey-bee this is reversed, and after the larval period her physiological energies are turned in another direction; she now makes wax instead of silk, the secretion of the salivary glands, never very abundant, is henceforth quite secondary to that of the abdominal fat masses, and loses all power of independent cohesion whatever.

Besides the salivary glands the thorax contains portions of the general circulatory, respiratory, and nervous systems, and the cesophagus on its way to the stomach. All these will be most conveniently examined in connexion with the abdomen, where, if not their most important, at least their most prominent portions, such as would be most likely to catch the eye of a general observer, are displayed. If exception be made to this arrangement in any particular it should be in reference to the respiratory apparatus, which is so highly developed in the thorax. Large air cells fill the spaces between the muscles, tracheæ ramify among their fibres with a minuteness not seen elsewhere, and it is the thoracic spiracles which are adapted in wasps to be the chief organs of

voice. Still, as, without the opportunity of studying it in the abdomen, we should know very little of their respiratory system, it seems best to defer its consideration till we can trace its development there.

We proceed, therefore, here to examine the external appendages of the thorax, the legs and wings. The legs of wasps are formed on the same plan as those of insects generally. The names of the different parts have been adopted from the limbs of Vertebrata. First comes a short flat joint, the coxa or hip, by which the limb is connected to the trunk. The next joint is a still smaller piece, which is let into the articulation, as it were, and thus gives a much greater extent of movement. This is the trochanter, on which the limb turns. The femur or thigh, which is so largely developed in the grasshopper and the flea, succeeds to this. It stands out almost horizontally from the body, and is probably the first in the series which would attract attention. Then comes the shank or tibia, the long straight bone which turns down towards the ground. The tibiæ of the two first pair of legs have only a single spine at the end furthest from the body, the distal end as it is called; while the hind pair have two of these spines: this is important to recollect. Otherwise they are unarmed; contrasting in this particular respect with the corresponding limbs of many of the sand-wasps, which are clothed quite down to the feet with strong hairs or spines.

The articulation between the thigh and shank bones is very strong. The form of the surfaces only allows of movement in one direction, being a hinge joint. The movement by which the limbs are turned

backwards or forwards is effected in the articulations between the smaller pieces which connect the thigh to the body ; and the extent of this movement is much greater in the fore-legs than in the other limbs. These parts are all comparatively rigid, but the mode of arrangement of the tarsal joints, which come next under consideration, gives the limbs the requisite amount of elasticity.

The tarsi in wasps, as in all other Hymenoptera, are five-jointed. In wasps the first and last joints are longer than the rest ; but none are of very disproportionate size. This circumstance, as already noticed, supplies an important distinctive character between wasps and bees, the first or proximal joint in bees, and particularly in the honey-bee, being much enlarged, flattened out and fitted with rows of hairs, called, from their use, pollen-brushes. Poets, into whose dreams the homologies of the insect skeleton



Fig. 3.—Comparative view of the posterior tarsi of the wasp and honey-bee.

- a, tarsal joints of the honey-bee, with the first joint disproportionately larger than all the rest, and the tarsal hooks denticulated, as in the solitary wasps.
- b, tarsal joints of the wasp, with the first joint narrow, the tarsal hooks simple, and the end of the tibia armed with two spines.

never entered, have incorrectly called this over-developed joint of the foot the bee's thigh. Each of the tarsal joints consists of a wedge-shaped piece, the point of which is received between the open horns of the preceding member. The ends of the horns of the last piece are not armed with spines,

but rounded off, so as to leave room for the free play of the foot, which forms a kind of sixth tarsal joint in which the limb ends.

The most prominent feature in the foot is a large pair of claws, one on each side. These, it should be particularly noticed, are simple in the Vespidae, while in the Eumenidae they are toothed in their concavity. This rule has no exceptions.* Between the tarsal hooks we find the pulvilli or cushions on which the insect treads. These are covered on their plantar surface with minute hairs, some of which are hooked at their extremities, and others are bulbous, reminding one of the bulbous suckers with which the arms of the star-fish are provided. It is by means of these bulbs that the foot clings to smooth and polished surfaces; but whether by atmospheric pressure only, or by the aid of a glutinous secretion, does not seem absolutely certain.† Though the increased difficulty with which a fly makes its way over a pane of glass damped by the breath seems strongly to favour the first opinion.

The insect sucker consists essentially of a hair, with its extremity dilated into a bulb and hollowed out in the centre. This is seen in the most perfectly developed form on the fore-legs of our great water-beetle, *Dyticus marginalis*; and the same form of instrument, only very much reduced in size, is set over the pulvilli of the fly's foot, where there is no great difficulty in recognizing it. It requires, however, a high power of the microscope, and a careful

* De Saussure, 'Guêpes Solitaires,' tome I, p. xix.

† See on all this subject, Tuffen West, On the Foot of the Fly, 'Linnæan Transactions,' Vol. XXIII, p. 393.

dissection, to display these suckers on the pulvilli of the wasp, which has these parts altogether smaller and much less distinct than many of the Diptera.

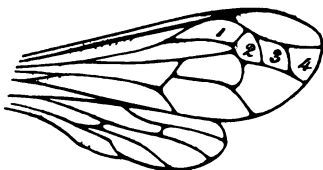
Indeed, the bulbed hairs on the wasp's foot, which are meant for suckers to act on smooth surfaces, do not seem to play as important a part in her progression as the little hooked hairs, which are mixed with them, and are as obviously meant for holding to rough surfaces. Wasps do not appear at all at ease on a polished surface: they cannot walk readily up a pane of glass, as their hold is less perfect, and their bodies are heavier in proportion to the area of their feet than those of flies. They walk much better on the rough surface of their own paper nests, where their tarsal hooks and the little hooked hairs of their pulvilli can be of use, than on the window-panes. And they do not seem to take the same quiet monotonous pleasure—happily—as our domestic flies, in walking about the windows; it is a scramble up and a tumble down, and the sash-bar proves an obstruction only to be surmounted by the aid of their wings.

The wings of the Hymenoptera supply the characters by which this large Order of insects is scientifically distinguished from the others, and is familiarly recognized. Some of the most valuable specific distinctions between the various subordinate genera are also derived from the wings. But, for this purpose the fore-wings alone are employed. Whether the arrangement of the nervures in the hind-wings is as various and as constant for each subdivision as in the fore-wings I cannot say. At least, the varieties

have not been as accurately described here as in the fore-wings. Easy of recognition, capable of being committed to paper, if not to memory, at once and without any dissection, unfailing in their accuracy of definition, it would be impossible to overrate the importance of these characters for this purpose. But it would be useless to try to convey a correct idea of the arrangement of all these markings without the aid of diagrams or properly arranged specimens. With the aid, however, of a correct drawing or of a wing spread out on a piece of white paper, we may learn most of this important lesson without difficulty.

Fig. 4.—Nervures of the wings of the hornet.

The four cubital or submarginal cells are indicated by the numbers.



Thus,—on the front edge of the fore-wing is a dark spot called the stigma. A line curving outwards and backwards from this point forms the posterior boundary of an elongated oval space. This line is the radial nervure, and this space is the radial or marginal cell. To the posterior convex side of this cell parts of four spaces fit. These are the cubital, called also the sub-marginal cells;* for nomenclature has been very busy, causing confusion

* See: an elaborate paper by Mr. Shuckard, whose nomenclature I have adopted side by side with that of Latreille, in the 'Transactions of the Entomological Society of London,' Vol. I, p. 208. 1836. 'A description of the superior wing of the Hymenoptera.' There are ten systems of nomenclature, more or less different from each other.

here, and these little spaces and wandering lines have more than one set of names. The second and third of these cells, counting from the root of the wing, are the most important; their shape, their proportions to each other, and their connection with the various nervures being points to be specially attended to. The third cell is irregularly quadrilateral. The second is irregularly hexagonal; it is in contact with the marginal cell already described, by a broad surface, not by a narrow neck; and its bounding line inosculates with two lines called the recurrent nervures, as well as with the line which bounds the first cubital or sub-marginal cell. To assure ourselves of the reality of these distinctions, and to fix all these details exactly in the memory, we should compare the wing of a wasp with that of a bee, or with that of any of the little wasp-like insects which we may find in flowers.

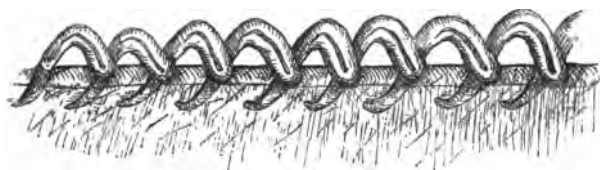
These nervures are the frame-work over which the membrane of the wing is spread. They give strength and direction to its blow, and radiating backwards from the root of the wing, assist in its feathering. The nervures are, or were in their first development, essentially air-tubes, and, as such, are lined with a spiral thread, which may be traced in some of the fine ramifications in a modified form. At the root of the wing, where they are gathered together to form the articulating surface on which the wing moves, they are thickest, and from this point they fade away till they are lost in the membranous expansion near the edges. The root of the fore-wings is covered in front by a small membranous scale called the tegula or wing-cover. The hind wings have no tegulæ, and are not folded in repose like the fore-wings.

The membrane of the wings which is spread out on this frame-work is twofold, the nervures lying between the two layers, like the sticks in a paper fan. The outer surface is set with small short hairs or bristles which are most largely developed on the front edges of the wings. On the front edge of the hind pair, these hairs are for a short space still more enlarged, and turned over so as to form a row of spiral hooks. These hooks vary much both in form and number in the different orders of Hymenopterous insects. In all the female Vespæ which I have examined, both English and foreign, there were thirty-two hooklets. But in the males, both of the hornet and of the smaller species of English wasps, the number was considerably smaller and very uncertain. One had thirty, one twenty-eight, one only fifteen, but the greater part had from eighteen to twenty hooks. In one *Odynerus* there were fourteen only, while in different species of sand-wasps from Penang they ranged from nineteen to fifty-seven. Mr. Newport* infers, from the occurrence of a smaller number of hooklets in the weaker flying of the two sexes, that their number has a direct relation to the power of flight. Thus, the feebly flying male of the humble bee has only eighteen, while his partner has twenty-five; and, conversely, the male of the honey-bee, which flies so strongly, has twenty-one, while the female and worker have only seventeen and nineteen respectively. I would not question the general inference, but I doubt whether the numbers are constant enough to build any accurate conclusion upon. The numbers in the female Vespæ have appeared to me constant. But I

* 'Cyclopædia Anat. Phys. Insecta,' Vol. II, p. 930.

make the number in the female humble-bee twenty-three only, and in the Ligurian honey-bee, seventeen in the male, twenty-three in the worker, and eighteen and twenty on the two sides of the female in my cabinet. They are seen to greatest advantage in the humble bee, but they come out very beautifully, like a rope-moulding, in the hornet, as shewn in the accompanying sketch. Corresponding to the row of hooklets

Fig. 5.—Diagram of the hooklets on the hind wing of the hornet, seen from the lower surface.



on the hind wing is a crest on the posterior edge of the fore-wing, forming a ledge beneath which the ends of the hooks catch. The points of the hooks turn up, and the corresponding ledge or flange turns down to meet them.

The locking of the wings in Lepidopterous insects is effected by a different mechanical arrangement to that which obtains in wasps and bees. Thus: parallel to the front edge of the hind wing, and springing from its root, is a long, strong bristle. Near the root of the fore-wing, a slight horny process, somewhat hooked, rises from one of the nervures. The bristle is readily caught by this, or by the tuft of hairs which in some species answer the same purpose, so that the locking or unlocking is effected in a moment. The apparatus varies in form in different species, it is found chiefly among the moths; my own observations

were made on a humming-bird moth. Butterflies, whose up and down flight contrasts strongly with the smooth rapid course of the sphinx-moths are entirely destitute of it.*

Other forms of locking-gear are found in the Hemiptera. The *Notonecta*, or boat-fly, which we know best as it sculls along on its back, locks its wings in flight by means of a little hook which plays along the front nervure of the hind wing. This hook springs from the under surface of the fore-wing, at the point of junction between the clavus and the membrane of the elytron. And the same form of hook is found in the tropical *Belostoma*, one of the Nepidæ, an insect whose large size adapts it admirably for the examination of the organs of flight. In the British representative of the Nepidæ, our water-scorpion, the hook is made by the edge of the clavus being turned down. The outer half of this edge hooks into the hind wing in flight, while the inner half locks the elytron, in repose, to the edge of the thorax. Unless we bend the thorax, and so loosen the catch on its posterior edge, just as the insect would do, in preparing for flight, by the action of the muscles, it requires a great deal of force to spread the wings of the larger species.

In the locking-gear as displayed in these different instances, and probably many other similar ones might be found on more extended examination,† it is to be observed that the wings are not merely hooked together, but that provision is made to keep them parallel and in contact during motion. The connec-

* See Westwood, 'Modern Classification,' Vol. II, p. 317.

† See references, 'Cyc. Anat. Phys.' II, p. 931.

tion is not effected by a hook and eye, but by a hook or hooks sliding on a bar. As the wings move forwards to expand, and to take their position for the proper muscles of flight to act upon them, the hooks catch of themselves, and they are not put out of gear till the wings resume the position of rest. This arrangement is constant, but which wing shall furnish the hooks, and which the slide-bar or catch, depends on the anatomy of the particular family.

One more point yet remains to be considered in the structure of the wings. Still speaking of the fore-wing, which in the wasp is essentially the stroke-oar, we find that its nervures, as they become thicker and stronger on approaching the root of the wing are gathered into three ridges, forming a narrow neck. From this neck, just as in our bones, the condyles of the joint take their origin. The form of the condyles or articulating surfaces scarcely admits of any exact measurement in such a small speck as the root of a wasp's wing presents. The necessities of the case, however, show that the form and mode of attachment must be such as to allow for a movement in a horizontal direction—as the wasp stands—from the position of repose to that of extreme extension. A vertical, or up and down movement, and a rotatory, or feathering movement, have also to be provided for, in combination with this, in the mode of articulation of the wings. The human anatomist scarcely needs to be reminded of the resemblance of this compound movement to that which is provided for so exquisitely in our wrists and elbows, and in each case by a different mechanism. As the wasp stands, the roots of her wings are very nearly in the same

horizontal plane. But as she lies obliquely on the air in flight this plane slopes downwards and backwards, so that the down stroke of the conjoined wings must be delivered forwards.

It is quite unnecessary to say that a mere flapping of the wings, to and fro, however rapid, regular, or long-continued, could not do anything in the way of flight; it would disturb the air and nothing more. Some arrangement must be adopted to render the stroke more effective in one direction than the other. To explain how this is accomplished will require, and must excuse, a long digression on the mechanism of flight.

The problem of flight has always attracted much attention, and, from the time of Dædalus downwards, mechanical invention has been strained to contrive flying machines on the most various principles, all agreeing only in one point, that of failing to accomplish their object; all legends to the contrary notwithstanding.* The Aëronautical Society of Great Britain† has had no better success as yet than private adventurers in the same field of air, but we are much indebted to it for having elicited an essay from Mr. Wenham,‡ explaining the correct principles on

* See Browne's 'Religio Medici,' Gairdner's edition, 'p. 38, and Appendix C, for references on this subject to Du Bartas and others.

† 'First Annual Report,' small 8vo, London, 1866, records some very curious experiments on aërostation, and enumerates no less than forty patents which have been taken out since 1842 in connection therewith.

‡ On Aërial Locomotion, and the Laws by which heavy bodies impelled through the air are sustained. 'Engineering.' Ap. 19, 1867, p. 360, and 'Annual Report,' *sup. cit.*

which a flying machine should be constructed. From this, and from a Lecture by Dr. Pettigrew,* I have endeavoured, without entering too deeply into the question, to gather as much as may be read with interest in connection with the flight of wasps. Though the flight of insects is only discussed incidentally and by way of illustration to that of Birds by the Duke of Argyll,† yet I must add his thoughtful work to the list of authorities on this subject.

The first thing to be attended to in the construction of a flying-machine is of course how it shall support itself in the air; for such a machine, to have an independent motion, must be heavier than the surrounding medium. This principle is not satisfied in the construction of balloons; these cannot be regarded in any proper sense of the word as flying machines; they simply float about in the air, while the supporting power of the gas lasts, whichever way the wind may drive them. And our power of guiding these unwieldy monsters is limited pretty much to raising and lowering them, and to taking advantage of the different direction of the currents of air to be found, if so it should happen, at different heights. A parachute perhaps is a step nearer to a real flying machine, though it can only be compared to a flying squirrel, or to a beetle deprived of its wings dropping gently down, by the aid of its elytra, to the ground. A child soon learns to turn the supporting power of the air to advantage when he plays

* On the various Modes of Flight in relation to Aëronautics. 'Journal of the Royal Institution of Great Britain,' March 22, 1867.

† 'The Reign of Law,' small 8vo, London, 1867, particularly Chapter III, on the Machinery of Flight in Birds.

at ducks and drakes with flat bits of tile, and the Australian boomerang is essentially a flying-machine of the same humble order. So too, according to most observers, is the flying-fish. In all these, however, an initial impulse is necessary. Kites supply a nearer illustration of what the insect world displays in such infinite variety, successful flying-machines, though they have been oftener recommended than applied to practical uses. In kites the traction on the string may be taken to represent the weight of the body of the insect, which pushes it forwards and downwards, just as the string draws the kite in the same direction. In this instance the difficulty of supporting a heavy body in the air by mechanical means is fairly surmounted; but this is only half the problem of flight, for the string limits the range within which it can fly. And even this amount of success, and within these narrow limits, is dependent on the direction of the wind which supports the weight by its upward pressure.

It might seem that the proper way to investigate this question would be to study the sustaining and the propelling principles separately. This may be done to a certain extent; and the beetle, indeed, supplies a living instance where the instruments of support and propulsion are distinct, being represented by the wing-covers and the wings respectively. In wasps, however, which are the example which we have to keep constantly before us, the two functions are inseparably united; and, generally speaking, the difference between support and propulsion is a mere matter of direction. Still, we may find an available distinction according as the current of air, and the influence of gravity

act on the passive insect body, or as the insect itself acts on the surrounding medium. And I have arranged, as far as practicable, the successive steps of this inquiry according to this view.

As to the PASSIVE element: Mr. Wenham calculates that the area of the supporting surface bears the proportion of about one square foot to each pound weight to be supported. This would secure a descent of no more than twenty-two feet in a second of time at an uniform velocity: being the speed at which one meets the ground at the end of a drop of eight feet. This proportion is pretty generally observed in different kinds of birds, "hornets, bees, and other insects." But there are some striking exceptions, "some of the duck-tribe, classed among the strongest and swiftest of flyers" having little more than half that area of wing.

Having thus ascertained the extent of the surface which should be opposed to the air, we have next to consider the influence which the form and direction of this surface exercise. A round body heavier than the air, such as a bullet, falls straight to the ground through still air; or in a wind it falls diagonally. If this same body is flattened out to an area duly proportioned to its weight, it falls straight through still air, only more slowly. But in a wind it will fall more or less obliquely, or it may even rise, like a kite, according to the force of the wind, and the direction in which the wind meets its surface. So it is with insects or birds. A dead beetle or rook falls like a plummet: a live sea-gull, as motionless all the while as a dead rook, soars with her wings extended, driven upwards by the air through which she is

falling. Wasps cannot soar, and their wings are never tranquilly extended in the air, but the form and position of their bodies are as important elements in their flight as in that of the sea-gull, and, however disguised or complicated, the principles which sustain and direct them are the same as those which sustain and direct the kite or the ball.

In such little creatures we cannot take exact measures of all the curves of their surfaces. But we may safely assume that their *lines*, as a ship-builder would call them, are as accurately adapted to their physical requirements as is the rest of their structure. Designed always to sail on a cross wind, they are doubtless formed so as to sail as near the wind and make as little lee-way as any vessel. In other words designed to fly horizontally, under a downward pressure, they are doubtless formed so as to fall as little, and to advance as much, as possible.

Then, as to position. A bird falls when it is winged, and a ship, unless her sails be drawn to the right angle, and her head be kept straight in her course, is no better than a log on the water. We cannot watch these little atoms very closely as they flit by us, but we can learn from the examination of their bodies, that they have means, as effectual as a ship's rudder, for keeping their course. Bearing in mind that the pressure on an insect is obliquely vertical, not obliquely horizontal, as in a ship, we shall see that everything has been most amply provided for. A wasp can raise or depress her abdomen at will, and so alter the angle at which she lies on the air; she can trim her balance from side to side by means of her air-sacs; and she can adjust her wings, as exactly

as the sails of a ship, to the direction of the current of air.

Thus far of the passive instruments of flight, of the means by which a heavy body can be supported in the air, without any greater effort of its own than putting itself into the proper position to be helped. Turning now to the ACTIVE elements, we find two most important principles clearly laid down with regard to the use of the means of propulsion. First, the propelling power of a wing, as measured by the rapidity of flight, the strength being the same, is proportioned to its length rather than to its width. A fact which is turned to practical use in the construction of the fans of screw-propellers. And next, for the fans or wings to work to advantage, they must strike on *dead air* or *dead water*, that is on air or water which has not already been set in motion by, and is slipping away from, them. The distance to which the air is set in such motion by the wings of a bird is very short. For instance, birds do not ruffle the surface of the water, however closely they may fly over it. But within this distance a bird flies under as great disadvantages as a swimmer who is struggling against the stream with the water slipping away from his stroke. Bearing in mind that a bird moves in a current, as it were, falling straight down to the ground, and that all blows given directly downwards are given in air slipping away from the wing, we see at once the reason why none but the very strongest flyers can ascend vertically, but must soar round and round, towering up as it is called. When birds or insects try to poise themselves in the air, the rapid fluttering of their wings, under these

circumstances, shows how very difficult it is for them to keep in the same place. And for the same reason that they cannot rise, namely, that so much of the force of the blow is lost on the moving air, in what is technically called *slip*. The maxim, that you must learn to stand before you try to run, scarcely holds good beyond the walls of the nursery. And it has no application whatever to the art of flying, any more than to walking on stilts or swimming. To stand still is one of the most difficult feats in flight.

But when the place of the insect is being constantly changed, when each beat of the wings takes them out of the range of the influence of the last beat, and places them in a resisting medium, their movements are much more easy. Besides, each yard of space traversed contributes something of upward pressure to the support of the bird or insect lying obliquely on it. And, at a high speed, the total amount of the upward pressure over a long path, in other words, of the support from the air itself, is something very considerable.

The adjustment of the wings is at once the most intricate and the most interesting part of the problem of flight. Much of what has been already passed in review can be explained on mathematical principles, and much we can actually imitate by mechanical expedients. But here, in the rapid motions of these little organs, observation is taxed in collecting the materials for a scientific induction, imitation quite fails us, and it is as much as we can do to interpret the results with any assurance of correctness. With such reservations I venture on the following explanation of the movements of flight in wasps:—

The motions of which a wasp's wings are capable, according to the form of the articulating surfaces and the movements of the thorax, are up and down, and backwards and forwards, with a slight rotatory motion. And during all these movements there is a special arrangement for keeping the wings parallel to each other. The action of the great muscles of flight is directed to the alternate raising and depression of the arch of the meso-thorax, to which the fore-wings are attached, and the motions of which they follow. The hind-wings, while they are locked, must of course vibrate with the fore-wings, but they make the stroke oblique as they hang behind it. And the same thing occurs on the return stroke, which is effected, not by a spring, but by another set of muscles, the fore-wing still leading. The result of this is to produce a figure-of-eight movement; so that the one half of the vibration is not the exact counterpart of the other, but a blow is given with more effect in one direction, that is on the down- than on the return-stroke; the anatomical arrangement determining in which direction the more effective stroke shall be delivered.

The wings, in their combined action, have a much greater forward-propelling power than when separate. The flight of many moths which lock their wings, as compared with that of butterflies, which do not lock them, is an instance of this. Now as it is length and not width which propels, the two separate narrow wings should give a greater speed than the broad wing which results from their union. And it must be by modifying the direction of the blow that the locking of the wings tells on the speed, as on

the smoothness of flight. The dragon-fly, the swallow of insects, may seem to constitute an exception to this rule, as her wings do not lock. But the cases are not strictly comparable, as she has an exceptional power of altering the direction of her wings, in connection with the unusual mode of the insertion of her muscles of flight. Having already spoken of these, I would only remark further here, that there is something so peculiar in the flight of the dragon-fly as might lead one to predict, even without anatomical demonstration, the existence of some peculiar structural arrangement of her wings. If we watch her over a pond we see how she stops suddenly in the most rapid dashes, and, for all her strength of wing, seems to have more frequent need of rest than most other insects. And, rapid as her flight is, she is readily caught by a quick hand, as she comes staring and rustling in our faces.

The action of the wings is most easily observed when they are separated. As the pretty *Syrphus* hovers over a flower, the position of the elliptical figure which her wing describes shows that the vertical extent of movement is greater than the horizontal; indeed it must be so, or else she would advance. By the same mode of reasoning it is clear that the downward blow must be stronger than the upward; the wing must be feathered on the return stroke, or else she would fall. So, when the wasp poises herself, she unlocks the wings, and all forward motion is at once stayed. I have often seen this, in the window-case where all my working wasps' nests are placed. The unlocking of the wings seems as necessary a preliminary to the landing of a wasp, as

the turn which a rook gives her wings to lift her up before she steps on the ground. Under these circumstances the end of each separated wing describes an elliptical figure, standing vertically, or nearly so, just as in the *Syrphus*. The same may be seen in a humble-bee, as she scrambles, rustling and humming, up an inverted tumbler held obliquely towards the light.

When the wings are locked together and vibrating in unison, in rapid flight, we cannot of course follow the outlines of the figures which they describe. But we know that they must trace a series of cycloidal curves along the line which the insect follows, which are wider according to the rapidity of the flight.

Fig. 6.—Diagram shewing the figure described by the wings of the wasp in flight: the thin line is an imaginary section of the wing in the up-stroke, the broad band represents the space covered during the stroke given downwards and forwards.



ring the stroke given downwards and forwards.

And the little creature may be compared to a steamer urged on by two paddle-wheels which are of a size wholly disproportioned to her tonnage, and in which all the difficulties of feathering floats have been happily solved. It might seem, at first sight, that to drive the insect along forwards, and to support her in the air, the blow of the wings should be given downwards and backwards. But Dr. Pettigrew, whose assistance and personal courtesy in investigating this subject I have great pleasure in acknowledging, from careful examination of the whole question, concludes that the stroke is given down-

wards and forwards. And I quite accept his conclusion as correct. Apart from various other considerations, which it would occupy too much space to discuss here, one very strong reason against the commonly received opinion of the wings striking backwards, is that the wings do not move easily in that direction. We may learn something from a recently killed hornet. If we press the thorax alternately in the direction in which it would be drawn under the influence of the muscles of flight, the wings strike downwards and forwards. In the large water-scorpion the direction of the movement is very obvious: for here the strength of the parts makes the direction which the wings take when coupled, and from which they cannot be made to deviate except by force, quite distinct. The coupled wings cannot strike downwards and backwards. Again, where the wings are free, as in butterflies and dragonflies, the change from the position of rest to that of extreme extension is still downwards and forwards.

Not to prolong this inquiry there is yet one other point for consideration. Mr. Wenham thinks that the amount of muscular force requisite to raise and maintain a heavy body in the air is not as great as is usually supposed, but after all allowances made, it is still very considerable. For, if we are to judge of the work to be done by the means which are provided to do it with, we can come to no other conclusion than that half the secret of the flight of insects lies in the enormous and untiring muscular power which is stowed away in their thorax. The strong, rapid action of their muscles is to be mea-

sured by thousands of strokes in the minute, their endurance by miles and hours of flight.

Interesting as this problem is in the thought that perhaps such abstract speculations may be some day turned to practical account, yet a physiologist can scarcely help dwelling on the fact that size seems to set limits to the denizens of the air, as it does to those which walk on the earth, and, with a wider margin however, to those whose bulk is to be supported by the waters of the sea. If we hope ever to make the air available for purposes of transit we must look beyond animal substances for materials. Something more than muscle is wanted to supply the strength, something more than bone to bear the strain to be put on it. But steel and the sources of steam are too heavy for flight, and the vapour that will submit to be pent up in a bottle, like the Efreet in the Arabian Nights Tales, and to be practically applied to the feat of driving us safely through the air, has yet to be discovered.

CHAPTER V.

ANATOMY AND PHYSIOLOGY.

ABDOMEN. EXTERNAL SKELETON. MUSCLES. RESPIRATORY SYSTEM.
SOUNDS PRODUCED BY INSECTS. ORGANS OF CIRCULATION. NERVOUS
SYSTEM.

WE turn next to the abdomen, the third great division of the insect body. The external conformation of this part in the *Vespæ* is very characteristic of the family. It is cylindrical, tapering towards each end. At the caudal extremity it runs on to a point, but forwards the abdomen suddenly contracts into a narrow stalk called the pedicle. The wasp is not more proverbial for the quickness of her temper than for the slenderness of her waist. In some of the solitary species, this pedicle is longer, and scarcely thicker, than the tibiæ of the insect, swelling out gradually into the first ring of the abdomen. In the *Vespæ* it is short, and does not gradually expand into the first abdominal ring, but springs out almost at a right angle; the square truncated end of the abdomen being one of their typical characters.

Four of the thirteen segments of the larva have been already accounted for; namely, one in the construction of the head, and three in that of the thorax. The fifth segment makes the pedicle which unites the thorax to the abdomen. This tube, so slight in

appearance, is of great strength and well calculated to defend from injury the important connections which it maintains. Next to this follow the rings—six in the female and seven in the male—each representing a larval segment, which compose the tegumentary skeleton of the abdomen. The remaining larval segments, two or three, as the sex determines, are absorbed in the composition of the sting, saw, borer, or analogous organ with which Hymenopterous insects are provided. The larva in this Order has the exceptional number of fourteen segments, but the supernumerary segment, though it may enter into the composition of the supernumerary organ in the perfect insect, is not to be regarded as its larval representative.

The abdomen is united to the thorax by strong ligaments, and besides these, there is a strong fibrous cord which, emerging through a notch in the post-scutellum of the meta-thorax, is inserted into the upper surface of the pedicle. The structure of this cord shows it to be, not an elastic ligament like that which supports the heavy heads of the Ruminantia on their long necks, but the tendon of a muscle contained within the thorax, by which the abdomen can be raised at the will of the insect.

Each of the abdominal rings is made in two pieces, a dorsal and a ventral scale. The dorsal overlap the ventral scales, and each ring is overlapped by that immediately preceding it to a variable extent. The apparent size of a wasp depends much on how far the abdominal rings are drawn in or out, and to obviate any uncertainty from this cause, the measures of its length are often calculated no farther than to the

posterior edge of the second ring, which does not move so freely within the one just before it as the others do. The second abdominal ring, corresponding to the seventh larval segment, is the largest of the series. In the Vespidæ, however, it does not predominate over all the rest to such an extent as it does in the Eumenidæ, where it is large enough to receive—*emboîter*, as the French word neatly expresses—all the following rings, like the joints of a telescope.

The part of the scales which is usually exposed to view is set with fine hairs; that which is for the most part covered by the preceding ring is not thus clothed with hair, but is finely wrinkled, like Morocco leather, on the surface. The connection of the several rings is effected by a thin transparent membrane, elastic, not muscular. This membrane takes its origin on the inner surface of the scales, along the devious, sometimes obscure, line where the colour of the scale changes from dark to light; and, passing forwards, is attached to the front edge of the succeeding ring. By this arrangement a considerable amount of longitudinal expansion of the abdomen is allowed for, fully equal to one-third of the width of each ring. The lateral expansion is much more limited.

The lateral cusps of the dark belt on the dorsal scales mark the points of insertion of two little slips of muscle; and two corresponding dots on each of the ventral scales give attachment to two more such slips, four in all, from each abdominal ring. They pass forwards and outwards to their other point of attachment, which is found, less definitely, in the soft surrounding parts and in the spur which rises

from the anterior edge of each scale at either end. If all the muscles act together the whole abdomen is contracted. If only a portion of them act, on the ventral or dorsal surface, or on either side, for instance, that side is contracted, but the opposite side is lengthened. With the power of admitting and excluding air at will, and thus of changing the fulcrum on which they act, this simple arrangement of the muscles is quite sufficient for all the requisite movements of the abdominal walls, which may be drawn out to their full length by alternate contractions of the opposite sides, or turned in any direction.

The little slips of muscle may be traced without difficulty from the black dots which mark the points of their insertion into the abdominal scales. If we wish to carry our researches into this matter further, we must examine other insects and at a different period of their existence, and we shall do well to avail ourselves of the labours of other anatomists.

For we shall gain a much more adequate idea of the elaborate nature of the muscular system of insects from a plate of the muscles of the cockchafer or of the privet-moth caterpillar* than from anything we may make out for ourselves, even in the largest hornet. Unless we devote a very large amount of labour, at a great expense of eyesight, to the subject. And the subject is scarcely worth it, for the arrangement of the muscles presents infinite varieties in different orders of insects, and in the same insect at different stages of its existence.† The muscles, like,

* 'Cyclopædia of Anatomy and Physiology,' Insecta, Vol. II, pp. 937, 940.

† Van der Hoeven, 'Handbook of Zoology.' Trans. Vol. I, p. 284.

or, if possible, even to a greater degree than, every other structure are adapted to the special requirements of the insect, and an exact knowledge of the muscular system of the wasp might scarcely apply beyond the particular family.

Within this expanding case are inclosed the digestive and reproductive organs, the centre of the circulation, and, if not the most important, at least the most obvious portion of the nervous and the respiratory systems. Now, it may seem sometimes as if we had quite lost sight of the proper subject of these pages while tracing the anatomy of these different organs on other insects more suitable for the purpose than wasps. But here, as with regard to the muscles, if we learned no more than the structure of wasps could teach us, we should know very little about the matter. We shall find indeed that, with all the aid that comparative entomology can give us, the limits of our knowledge on many points will still be very narrow. It will be necessary to examine each of these systems separately. And first, of the respiratory system.

The first object of respiration is, of course, the oxygenation of the blood. The general principle is the same in insects as in the higher animals. Air is pumped in and out alternately, the same passages serving for the entrance of the pure element, and for its discharge from the body loaded with effete matters. But insects differ from the higher animals in having many passages by which the air is drawn in and out, many pairs of lungs, instead of only one. They differ, as we shall see further on, in the way in which

the air is applied to the renovation of the blood. And, generally speaking, the relations between the respiration and circulation in insects are just the reverse of those which obtain in warm-blooded animals with heart and lungs. These differences will all appear as we successively examine the different portions of the respiratory system,

The respiratory movements may be observed very easily in any wasp that will stand still. The upper surface of the abdomen is alternately lengthened and retracted, and the air follows these movements through the spiracles. If we place a wasp in a live-box, under a low power of the microscope, we may observe an alternate undulatory expansion and contraction of the large air-vesicles between the first and second ventral scales. A very gentle compression must be used, only just enough to steady the insect under examination, or the motion will be interrupted. The number of respirations in a minute varies, as in the higher animals, with the amount of labour which they may have recently undergone, or the degree of present excitement. In the honey-bee the number varied from eighty to one hundred and sixty, as observed by Mr. Newport,* and in some insects of this order the number was even higher.

The stigmata, or external orifices of the respiratory apparatus in this segment of the body, lie in a row on each side, one at either end of each dorsal scale. They are to be looked for in the black part, where it overlaps the ventral scale, and is itself overlapped by the preceding ring when the abdomen is contracted. To the unassisted eye they appear merely as minute

* 'Cyclopædia of Anatomy and Physiology,' Vol. II, p. 988.

depressions, or pin-hole apertures. But, by the aid of the microscope, these holes are shown to have a crescentic or kidney-shaped outline, with a distinct raised edge round them. They communicate directly with the spiracles, and through them, by means of a short tube, with the great lateral air-trunks.

The thoracic spiracles of the wasp are larger than the abdominal, and seem to be her chief vocal organs. But the abdominal spiracles are more easily displayed, by reason of the looser structure of the surrounding parts and of the thinner integument in which they are placed. So we shall do well to begin with these, and, on account of her larger size, make the hornet the subject of our examination. The readiest way to prepare them is to remove the portion of the scale which contains them, dry well, soak in turpentine to make them transparent, and mount at once in Canada balsam. We shall require at least a quarter-inch object glass for the study of their details.

Beginning from the outer surface, we find that the horny ring which surrounds the stigma is thicker on the concave—as presented to the aperture—than on the convex margin. That is a thick rim; this is thinner, and gives origin to a broad membranous tongue, seen best from the outer side, which stretches nearly all across the opening of the stigma. Adjusting the focus so as to see deeper into the preparation, or turning the object over, we find a strong, rough membrane to arise from the inner surface of the thick concave rim of the stigma, forming a pouch, shaped like the letter D. A light, horny slip marks the line where the edge of this membrane seems to join on to the trachea. One end of this slip is turned

Fig. 7.—Abdominal spiracle of hornet, seen from the outside, through the integuments. The diagram shews the crescentic opening of the stigma, the tongue extending from the convex margin nearly across its orifice, the trachea lying parallel with the integuments just before it enters the spiracle, and the rudimentary hook appearing through its walls.



round into a hook, the use of which is more obvious, as we shall see, in the large thoracic than in the abdominal spiracles. The whole organ, as thus displayed, seems to be an oblique valvular mouth-piece applied to the end of the trachea, one side of the trachea being continuous with the wall of the pouch, and the other with the membranous tongue, as shown in the accompanying diagram.



Fig. 8.—Imaginary longitudinal section of an abdominal spiracle.

a, Trachea.

b, Membranous tongue, closing the orifice of the stigma.

c, Line of union of the trachea with the spiracle.

d, Pouch of the spiracle.

It will be of interest to compare the structure of these spiracles with that of the corresponding organs of the humble-bee. Unlike the wasp, the humble-bee has her chief vocal organs in the abdomen, not in the thorax. These have been made the subject of minute examination by Dr. H. Landois,* from whose admirable Monograph on the Vocal Organs of Insects I have condensed their description. Here there is a horny ring, across which a membrane is spread like the head of a drum. This membrane is divided into two unequal segments. One, the larger, is rough, and strong, and thick, quite up to its edge. The other, the smaller segment, is thin and delicate, and

* 'Die Ton-und Stimmapparate der Insecten.' 8vo. Leipzig, 1867. Zeitschrift für Wissensch. Zoologie, Band XVII, Pl. II, fig. 19.

is supplied with an apparatus by which its edge can be drawn tight and laid in apposition with the strong edge of the larger segment, so as to close the passage between them. This is the respiratory larynx, nearly answering to our epiglottis, or to the upper larynx of birds. Its function is simply to admit or exclude the air. The proper instrument of voice, answering to our vocal cords or nearly so, is a little horny comb, which is placed across this cleft, and vibrates, like the tongue of a Jew's harp or accordion, with the passing current of air.

Turning now to the thoracic spiracles of the proper subject of this inquiry:—I regret much that Dr. Landois has not made the spiracles of wasps the subject of his special study, but has left us only the analogy of the corresponding parts of allied insects for our guidance. Really the difference between the vocal organs of the hornet and of the humble-bee is very considerable. After rubbing off the hairs from the outside of the thorax, we shall find the orifices of the spiracles, as already traced in the anatomy of the thorax, without much difficulty. They are linear, not mere pin-holes as in the abdomen, and slightly crescentic in form, with the convexity directed backwards. The meta-thoracic spiracle is somewhat the smaller of the two, but, being situated in one of the scales, and not, like the pro-thoracic, between two of them, it is more easily removed without any displacement of its parts. The integuments containing it should be sliced off with a sharp scalpel, making the specimen as thin as possible, so as to allow of the near approach of the object glass. And it will need all the aid of turpentine to make the dark horny

structures in which it is placed sufficiently transparent for our purpose.

Under the microscope the crescentic outline of the stigma almost disappears, and the opening assumes a long oval form. On one side, the posterior, it presents a thick, round overhanging lip, which is slightly striated transversely on the surface, and



Fig. 9.—Diagram of the right metathoracic spiracle of the hornet, seen from the outside.

On the left appears the thick margin transversely striated, and the horny slip into which the wall on this side is continued. On the right is the thin membrane, with the hook by which its tension is regulated. The membranous edge of the vocal larynx is not displayed fully in this figure.

hollowed out beneath. Farther in, this edge gives attachment to a membrane, like that which forms the pouch of the abdominal spiracle, and having the line of its connection with the wall of the trachea marked, in the same way, by a horny slip. The other margin is thinner and, again like the abdominal spiracle, gives attachment to a delicate membrane, the edge of which has space to play in the hollow just noticed behind the opposite overhanging lip. This is the vocal larynx, similar to that already described in the abdominal spiracles in its general structure, but more powerful as an organ of sound, from its larger size and the nature of the frame in which it is set, as well as from the freer current of air which can be sent through it. The instrument actually producing the sound seems to be the membranous tongue which vibrates in the hollow behind the thickened margin of the stigma. I have never

detected anything like the sounding comb of the humble-bee in the spiracles of any of the different kinds of wasps which I have examined.

As we follow the course of the spiracle still further in, it takes the form of a narrow flattened tube. The point of interest is its junction with the trachea. On one side this is marked by the horny slip so often alluded to, which is turned neatly round the flattened edges of the tube. From the opposite side a very delicate membrane projects into the canal to meet the slip. For about two-thirds of its length the edge of this membrane runs straight, but, at about one-third from the lower end of the stigma, the straight line is interrupted by the projection of the broad base of a flattened hook which rises from it. The point of the hook turns back and gives attachment to a few fine fibres, probably of the nature of muscle. The base is continued by one edge, round the trachea, into the horny slip which keeps all these parts in position, while the other edge turns up, and is lost in the delicate fold of membrane.

This is the respiratory larynx. In the larger, better developed thoracic spiracle, the use of the little hook, which appeared so enigmatical in the abdominal spiracles, is very obvious. The form of the external orifice of the stigma, and of the tube of the spiracle, differs much in the several kinds of Vespidae, but the arrangement of the membrane, and of the hook regulating its tension, is uniformly the same in them all. And though not identical with, it is strictly analogous to the corresponding part of the more elaborate mechanism which Landois has described in the humble-bee.

There is little to add with respect to the use of the spiracle as a respiratory larynx. Insect functions require that these little creatures should have perfect control over the ingress and egress of air, and the apparatus for this purpose is as simple as it is effectual. Flies have a screen of hairs across their stigmata, to prevent the introduction of extraneous matters, but wasps and bees have no further protection than that which their hairy body supplies: their habits of life probably rendering any such arrangement unnecessary. But with regard to the functions of the spiracle as a vocal larynx, there is much more to be said, and the interest of the subject will be, I am sure, a sufficient excuse for extending the inquiry beyond the range of the Hymenoptera. We can have no better guide than Dr. Landois* in this survey.

Speaking generally, insects produce sound in one of two ways, namely, either by attrition of their horny covering, or by a current of air setting membranes placed for this special purpose in vibration. Instances of the first kind of instrument, so to say, are found in the grasshopper, the cricket, the death's-head moth, and the death-watch beetle. The grasshopper rubs his thighs against the sides of the abdomen, the filed ridges of the legs and the sound-chambers beneath the abdominal scales being mutually adapted to each other, so as to develop the sound. House crickets make their loud chirping by rubbing the finely ribbed nervure of one wing against the other wing. And the death's-head moth rubs its

* See also on all this subject, Kirby and Spence, 'Introduction to Entomology,' 7th ed. p. 493.

horny palpi against its proboscis. The death-watch beetle, like many other insects which produce the same kind of sound, merely knocks its head against a post. In all these cases, except the last, where the sound depends more on the wood than on the beetle, and where no special provision has been made to increase the sound, air cavities are placed in the immediate neighbourhood of the rubbing surfaces. Without such an arrangement the sound would scarcely be audible at all, and by increasing the size of the air-chamber, as by holding a buzzing fly or bee on a sounding board, the sound is made very much louder. By proper manipulation of the various parts, many of the sounds of attrition peculiar to the different insects may be reproduced after their death. But I have never succeeded in thus reproducing those of the hornet or humble-bee.

This class of insect musicians may be said to play on stringed instruments, on the harp or violin. The other class are fitted with wind instruments which approach most nearly to the principle of the accordion, or of the toy mouth-organ. Perhaps some persons, not used to finding jewels in a toad's head, may prefer the comparison to that instrument of sound which is placed in the standing-board of all vocal toy-animals, from a lion to a lamb indiscriminately, whose note, so familiar to all who have little children, is produced by the sonorous vibrations of a membrane in a current of air. Foremost among those supplied with such spiracles we find the king of insect-songsters the classical Cicada.* Then we have nearly the

* It seems, by contrast with the mention of the cicada, quite an ungrateful task to be writing the history of wasps. The pleasant

whole order of Diptera, down, or more correctly up, to the mosquito with its note as sharp as its bite, some beetles, and, what chiefly concerns us here, the Hymenoptera. It would be the most proper course, perhaps, to study the subject of the insect voice in some of the members of this order. But wasps are obviously ill-fitted for this purpose. And humblebees are no better; they are so strong and so slippery that they need all our attention to prevent their putting their long stings through our gloves while we are examining them. The pressure too which is required to keep them quiet interferes much with the accuracy of any observations. We shall do better with some large Syrphi, familiarly known as bee- and wasp-flies. For they buzz much more loudly than the insects which they are named after, a finger is sufficient to hold them, and the absence of a sting makes them much more easy to handle than wasps or bees. The observation involves no pain or injury whatever to these pretty useful creatures, so that we need not scruple laying them under contribution for this purpose. Moreover, the mechanical arrangements are in them nearly the same as in wasps. Taking one of them in our hands, and fixing the various parts in turn with the point of a pencil, we can easily satisfy ourselves that the sound continues, though the wings and halteres are motion-

memories of the ancient cicada have not passed away with Anacreon and Virgil. They are reflected to us in England from the cricket, whose mischief is forgiven for his melody. Mr. Lord, in connecting the Zoology of the Old and New Worlds, dwells with delight on the discovery of a new species of cicada in the Rocky Mountains, as shrill and as tuneful as ever.—'The Naturalist in Columbia and Vancouver's Land,' London, 1866, Vol. II, p. 169.

less, but that it ceases as soon as the current of air through the tracheæ is stopped by pressure over the thoracic stigmata. Here is the chief cause of the sound; the vibration of the wings and halteres modifies it, but without a current of air through the trachea beneath there is no buzzing.

Incidentally this experiment shows that the air which is expelled through the thoracic spiracles to make the buzzing sound is also drawn in through them. For the abdominal respiration is stopped during this time by the pressure of our finger, and no air can come in by that way. Though the air tubes communicate freely, yet the respiration is maintained in them, as in ourselves, by a to-and-fro current along the same passages, not by a draught maintained in one direction, in at one and out at another set of spiracles, as in a coal-mine.

Hunter,* for whose observation nothing was too small or insignificant, noticed that bees still buzzed though their wings were rendered motionless by being smeared with honey; the tone was altered, but the sound continued. And when the bee was placed on water, with the buzzing, the water round the thoracic spiracles was thrown into vibration. Landois† has carried this branch of the inquiry still further. He found that the thorax of the honey-bee was still capable of buzzing, though in an altered tone, after it had been separated from all the rest of the body. And, that the sound was mainly produced during and by the emission of air from the spiracles, that is during expiration, was shown by the motion

* 'Works,' Vol. IV, p. 459.

† Op. cit. pp. 39, 62.

and direction which it gave to the buzzing trunk. The current was strong enough to drive the body of a fly deprived of its wings and limbs over a polished table, or over the surface of a basin of water. However it does not seem certain that the spiracles never sound during inspiration.

As the same movement which drives the wings secures a free current of air through the thoracic spiracles, the humming sound would most naturally be produced during flight. Indeed, our old friend the humble-bee—though, as she hums chiefly with her abdominal spiracles, this is scarcely a case in point—seems unable to move from flower to flower without this accompaniment. But wasps often fly quite noiselessly, as they pass along in a direct, but not very rapid, course. It is when they are angry and flying in circles about the room or round one's head, when they are about to alight, or when they first spring into the air, that they make the shrillest noise. It happens that at certain of these times the wasp has her wings unlocked. And something may perhaps be attributed to the stronger current of air playing on the wings which are not then vibrating in unison. But we may leave quite out of consideration the mutual attrition of the edges of their wings as a possible cause of the humming, for the sound produced by this means, which we can often hear very distinctly in the hornet, the humble-bee, and the dragon-fly, as their larger size allows, is a rustling, not a humming sound.

Besides the vibration of the spiracles, thoracic and abdominal, there is a very perceptible vibration of the head on the thorax in bees. This is not so

obvious in wasps. Bees indeed appear to have a more copious language in every way than wasps. Those who are familiar with bees and their ways can tell what is going on in their hives by the nature of the buzzing; there is a note of anger and a note of contentment; and the queen has notes of her own, well understood by her subjects. I am not aware of any variety of the notes in wasps beyond what have been indicated already, and indeed a wasp's nest, even during seasons of great excitement, is, quite unlike a beehive, an abode of silence. The audible expressions of temper are those of individuals not of the community.

From the spiracles, the tracheæ pass inwards, to join the large air trunks which run up the abdomen, one on either side. These are not disposed with exact symmetrical regularity, one answering to each other and to each of the segments of the abdomen; for they are an adaptation of the respiratory organs of the larva to the altered circumstances of the perfect insect. Instead, therefore, of presenting a symmetrical arrangement, as in the larva, of two lateral tubes, which are fed from the spiracles on one side, and give off branches regularly to all the organs on the other, the lateral trunks are dilated in some parts into large vesicles, while in other parts they are so contracted that it is difficult to trace their continuity. One such large vesicle is to be found on each side within the first and second abdominal rings. From the main trunks and the vesicles, air-tubes are distributed to all the neighbouring parts, incidentally serving a mechanical purpose by forming a loose

network round the viscera, which retains them in their places. One set pass half way across the abdomen, and join with corresponding branches from the opposite side, to form a secondary trunk which runs up the middle of the abdomen. This central trunk, curiously, seems to begin in the egg tubes, which are gradually transformed into tracheæ. As this central air trunk passes forwards it becomes larger, but it soon shrinks again; and it is finally lost behind the dilated end of the oesophagus, at the entrance to the pedicle.

The general arrangement of the respiratory organs, such as has been described above, can be followed by the eye, without any assistance from the microscope. But without this instrument we cannot form any adequate idea of the extent and minuteness of the ultimate ramifications of the air tubes. They are found everywhere, spreading out just like the blood-vessels of warm-blooded animals, and with a like due proportion to the organic activity of each part. In the neighbourhood of the uterus one could almost forget that one is looking at an insect structure permeated by air tubes, and not at the system of dilated and tortuous veins which is visible in the corresponding situation in one of the Vertebrata.

The air tubes have an outer and an inner coat, between which, to preserve their form, an elastic spiral thread is coiled. When the tube is torn across, the spiral thread may be uncoiled and drawn out, as from the tracheæ of plants, only not to such a length. The large air vesicles are also kept in shape in the same way by an elastic thread, though their form does not allow of the spiral coils being laid down as

regularly as in the tubes. When the vesicles are torn, as often happens by an unlucky scratch in dissecting, the fibres spring back and carry the tear, transversely to their direction, across the whole sac, leaving, as the result of our labours, nothing more than a membrane spread out, like a drop of wax, on the surface of the water. Such a membrane, however, displays well the structure of the air vesicles. As the tracheæ approach the vesicles their spiral fibre becomes broader and less defined, and is arranged with a little less scrupulous accuracy. In the walls of the air vesicle the threads are still more distant and less regular, and they have a woolly, even a wavy outline. On the coats of the air vesicles, and of the large air tubes in their immediate neighbourhood, many little specks are occasionally to be seen, the nature of which is a matter of uncertainty. I must ask pardon for venturing to express an opinion on a point which has been left unsettled by competent authorities, but these little specks appear to me to be oil-globules. The irregular mode of their arrangement, their occurrence in a part distorted from its original form, and above all, the fact that they may be removed and examined separately from the membrane, strongly confirms the view which their appearance suggests, that they are oil globules.

Insects breathe, as we have seen, and many of them audibly express their feelings, by means of the air; much as the higher animals do. But their respiratory system is not concentrated in one place, it is made up of many smaller similar systems, repeated over and over again, with a longitudinal as well as bi-lateral symmetry which is only one stage removed

from the radiate type of development. Other than respiratory purposes are answered by the peculiar form and mode of arrangement of these organs, and particularly of the large air cavities. One of these is the forcible distension of various parts of the body, so as to obtain a better fulcrum for, or change the direction of, the action of the muscles. Another, to which the large abdominal air vesicles mainly subserve, is that of altering the external figure, and shifting the position of the weight inside. The specific gravity of the insect is thus also altered, but this,* though very important to animals moving in such a heavy fluid as water, is of comparatively little consequence to those which move in the air. Flight is a question of well directed strength, not of weight, and the advantage of the diminution of specific gravity is more than compensated by the attendant increase of bulk. But the power of trimming the body by pushing the heavy stomach to one or other side, and of poising the whole body on the wings as a centre by lengthening the abdomen, both which can be effected by the expansion of the abdominal air vesicles, is very important. These reservoirs of air act also as springs to equalize the pressure of the intermittent respiratory movements, like the air chamber in a fire-engine. And they assist in those functions of the abdominal viscera which in the higher animals require the aid of the diaphragm. Further, they have their use in all those physiological processes which are accompanied in the higher animals by vascular turgescence, but in the insect economy by increased afflux of air. All these func-

* 'Reign of Law,' p. 151.

tions necessarily imply the existence of voluntary control over the admission and expulsion of air, and we have seen how it is provided for in the structure of the spiracles.

The organs of the circulation are altogether much more difficult to trace than any parts which have yet come under notice. None but a practised insect anatomist can hope to do more than obtain a view of some portions of the main arterial trunk, and not even this much can be effected without great pains and patience.

The movements of the wasp's circulation may be most easily watched through the transparent skin of the larva, by placing it in the live-box, with just pressure enough to steady it and to bring its skin into contact with the glass over a sufficiently large surface. The motions languish and cease if the larva is immersed in water. The actions thus observed, however, convey the impression of a very imperfect circulation, of mere motion rather than of motion in one uniform direction. For there seems to be nothing more than an imperfect peristaltic closure of a membranous tube.

We might naturally have expected to find the mechanical arrangements more complete in the perfect insect than in the larva. But Carus* assures us that it is not so. The heart, the central pulsating vessel, remains almost unchanged through all the metamorphoses; and the smaller ramifications of the blood-vessels, instead of being multiplied and de-

* Carus. 'Traité Élémentaire d'Anatomie Comparée.' Traduit par Jourdan. Tome II, p. 323.

veloped, fade away with the greater development of the respiratory system in the perfect insect. For now, he says, the air comes to the blood, instead of the blood having to go in search of the air. To obtain a view of the central trunk we must spread out the dorsal scales in one piece, previously cleared of all the abdominal viscera, and having only the lining of fatty tissue lying on them. If the specimen thus prepared and pinned out under water be examined in a good light, we shall observe a transparent line running down the middle, clearer and more transparent as the specimen is more recent. This is the heart, the main trunk of the circulation. Now, with a bent needle carefully scrape off this fatty lining of the scales, gathering it all up, heart and all, into a flake. By drawing on this, a long tube may often be extracted from the thorax and head, even up to the bifurcation of the vessel. By careful manipulation, alternately teasing and pressing this mass under water, much of the fatty matter may be removed, and the parts may be arranged for examination in glycerine, as a transparent object, under the microscope. The abdominal portion will now be seen to consist of a central tube, interrupted at regular intervals by a series of valves which are formed by a small piece of the tube being drawn in,—*intus-suscepted*, as anatomists call it—like the foot of a stocking. On either side of each of these internodes is a triangular strap of muscle tapering off to a point which is inserted into the corresponding dorsal scale. At the point of the strap the fibres are undistinguishable from those of ordinary voluntary muscle, but as the band spreads out to cover the vessel they

become smaller and are more closely united to each other. And the transverse markings so characteristic of voluntary muscle fibre become much less distinct. The intention of these triangular straps is to compress the vessel at successive intervals, and thus, by the aid of the valves, to cause the blood to flow in one direction. The long string which we have withdrawn from the thorax is simply a tube, with no further means of propelling the blood, or of directing the current, than what the muscles between which it passes may supply. It carries the blood through the thorax into the head, and there it divides into two or more terminal branches.

Further than this we shall not be able to follow this system of vessels; and the channels by which the blood is returned to the heart are quite beyond the range of ordinary observation. For the investigation is one of exceeding difficulty. The arrangement of the blood-vessels in insects, and indeed the fact of insects having any regular circulation at all, have eluded discovery till quite recent times. Hunter,* indeed, described the insect circulation in language which needs only extending, not correcting, to bring the description up to the level of the knowledge of the present day. But the evidence of the fact, apparent to him, was otherwise explained by Cuvier, and not till 1827 was the arrangement of the blood-vessels in insects fairly demonstrated by Carus.†

It is reserved for only the most patient and devoted students of insect anatomy to trace in detail all the channels by which the blood comes and goes.

* Hunter. 'Posthumous Works.' Vol. I, p. 107.

† See Owen, 'Lectures on the Invertebrate Animals,' p. 222.

By such observers, however, from an examination of the different insects best adapted for the determination of each single point, the theory of the circulation in insects has been fairly established. Thus, from the heart, on the dorsal surface of the abdomen, the blood passes to the head, as already described. The return of the blood is not effected by mere filtration between the tissues and organs, as was formerly supposed, but along channels quite clearly defined, though, from the thinness of their walls, well nigh invisible. One such venous canal is found in the track of the spinal cord, along the ventral surface of the abdomen. Another constitutes a kind of auricle, surrounding the heart, or ventricle, as we should now call it, and supplying it with blood through numerous transverse slits. And the so-called cavity of the peritoneum in insects is really a collection of venous sinuses, by which the blood can pass from the front to the back, to complete the circuit.*

The general plan of the circulation in insects then, seems not so very different from that which obtains in the higher animals; involving only a different mechanical arrangement. But in the process of blood-making, in the mode in which the heart is supplied with the newly made blood, and in which the blood itself is applied to its various uses, the insect economy presents great anomalies.

In the higher animals the blood is made by a most elaborate process, in organs specially designed for that purpose. It is oxygenated and depurated at certain points only, where special organs are placed, which have a certain duty to perform in these

* 'Cyclopædia of Anatomy and Physiology,' Vol II, p. 976.

respects. As it goes it gives life; it brings at the same time the air and the materials for repair; and it gathers up the various effete matters, each to be thrown off at the gate open only to that particular kind of impurity. Their blood is their life, and death soon follows the interruption of its flow.

But in insects all this is altered. The blood is made from the food at once, by simple secretion through the coats of the stomach and bowels into the irregular venous sinuses in which these organs lie. Here, without any intermediate elaboration, the fluid chyle, or blood, or both, as we may choose to call it, is received; and here, side by side, in the fluid, lie the air tubes which are to bring oxygen to it and the gland tubes which are to extract secretions from it. These several processes, which are, as a rule, kept so distinct in the higher animals, are here transacted, not merely in close proximity, but actually, as in the placental circulation, in the same vessels.

Again, the circulation in insects is carried on at a low pressure, and with none of that force which makes the blood spurt out in jets when an artery is divided. The reason is plain. Within the hard case there is little resistance to be overcome from surrounding pressure. Then again, as there are the means of oxygenation ready everywhere, there is no need for the blood to be hurried round the circle to the point where it may have its exhausted vitality renewed. So no more force is applied than will just keep it moving.

And lastly, with regard to the nature and the functions of the blood itself.* It is a transparent

* 'Cyclopædia of Anatomy and Physiology,' Vol. II, p. 979.

fluid, of a greenish colour, with a number of little round or oval cells floating in it, which are often rough on the surface, and are, on the whole, much smaller than human blood-globules. Perhaps these are not really blood-cells, only particles of fat.* The blood only brings and removes material; the supply of air is quite independent of the circulation. It is altogether much less important than the blood of the higher animals. It is small in quantity in proportion to the size of the animal; and its direct influence on the manifestations of life is very slight, much less, indeed, than the influence of air in the tracheæ. An insect will live and walk about for hours after the circulation has been interrupted by the removal of the abdominal viscera, but immersion in water is speedily fatal by obstructing the respiration.

The only portion of the nervous system which is likely to arrest attention on a cursory examination of the internal structures of a wasp is the chain of ganglia which lie just beneath the ventral scales of the abdomen. These need no dissection, but appear, on merely turning back the scales, as a row of little white knots on a double thread. Their importance, however, is not to be measured by their size, for these knotted threads are a portion of the central nervous system. From the knots or ganglia the little filaments issue which give motor power to the muscles; and the filaments which bring back sensations from the neighbouring parts tend to these ganglia as their several centres. The double thread connects them all into one common system. It extends the whole length of

† Van der Hoeven. 'Handbook of Zoology,' Transl. Vol. I, p. 259.

the body, from between the eyes to the root of the sting. In the larva there is a knot or ganglion—we had better retain the use of this word—for each segment. But in the perfect insect the ganglia are changed, like the segments, according to the importance which the several parts have assumed in the imago. Some shrink up and coalesce, others are much enlarged. The two first ganglia are closed up together to form the brain, and so the oesophagus, passing between the two threads, seems to perforate the brain. From the brain, nerves are given off to the eyes and to the antennæ. Thence the double cord descends, and passes along the lower side or, as we should call it, the front of the body, in the middle line, giving off at each of the ganglia nerves of motion and sensation, according to the various requirements of the adjacent parts; just as we see in the abdomen, only on a much more extended scale. The position of the spinal cord in front, instead of at the back of the insect, may seem as great an anomaly compared with our own structure, as the passage of the oesophagus through the centre of the brain. But it is the whole arrangement that is altered, not the relative position of these parts only. The cord is not merely pushed forward; it is turned round, so that the motor strings are still, as in Vertebrate animals, placed towards the interior, and the sensorial portion of the cord lies next the surface of the body. And the limbs too have changed their relations to the frame on which they are hung, as well as the spinal cord. For, as Burmeister† reminds us, the extremities, which in the higher animals are dependent on the spine, are in

* ‘Entomology,’ translated, p. 272,

insects, just like the central nervous system, connected with the sternum or front of the thorax.

Besides these nerves, which correspond to our cerebro-spinal system, and which we can fairly trace to a certain extent, there are others,* which we cannot trace at all in such minute objects as wasps, which represent the sympathetic or organic system of nerves. In these last, as well as in the nerves which belong to the cerebro-spinal system, the structure throughout is of the simplest kind. There are no separate tubes in which the nervous matter is confined; the cords answering to our nerves consist, not of bundles of hollow threads, but of rows of globules of nervous matter inclosed in one common delicate sheath.†

The physiology of the nervous system of insects is as simple as its structure. Our movements are directed by a single brain, a separation of the connections between which and the rest of the system is almost instant death. And so close is the sympathy between the nervous centre and the rest of the body, that a shock to it, from an injury of an important part of the body, is often fatal. Nothing of this kind occurs in insects. They have not one only but many nervous centres, neither any one of them, nor the whole of them together, having the same relative importance to the whole body as our single organ

* I must again refer to Mr. Newport's elaborate essay, 'Cyc. Anat. Phys. Insecta,' Vol. II, p. 942, for all beyond the most elementary statements as to the structure and arrangement of the nervous system of insects in this chapter. An excellent summary of what is known on this subject may be found in Van Der Hoeven's 'Handbook of Zoology,' Vol. I, pp. 276, 277.

† Burmeister. 'Entomology,' translated, p. 270.

has. Insects live and move after they have been deprived of their limbs, after the head, thorax, and abdomen have been separated from each other. They feel no shock after some of the most barbarous mutilations, but eat and walk about as usual. And the directing power which the brain cannot then supply to the headless trunk is furnished by the secondary nervous centres to the adjacent parts. The penalties which we pay for the enjoyable possession of a finely wrought nervous system, which thrills through the whole frame, are unknown to insects.

There are some popular errors in physiology which we would gladly allow to remain uncontradicted, and none more willingly than that which ascribes to insects a capability of feeling pain equal to our own. But it needs very little observation to show that the popular acceptation of Shakspeare's lines—I do not by any means commit myself to say Shakspeare's own meaning—is quite erroneous:—

The sense of death is most in apprehension ;
And the poor beetle, that we tread upon,
In corporal sufferance finds a pang as great
As when a giant dies.*

The chief use of pain, regarded from a physical point of view, is as a protection against injuries.† The capacity for pain is lavished on parts exposed to injury, it is withheld from parts which are otherwise protected from the dangers whose near approach

* 'Measure for Measure,' Act III, Scene 1. Knight's 'Shakspeare,' Vol. II, p. 424, note 6, *ad locum*, gives the entomologist's view of this question, maintaining the correctness of Shakspeare's own meaning against the commonly received interpretation of these lines.

† See on this subject 'Bell on the Hand,' 5th ed. p. 196.

pain would serve to indicate. The want of a capacity for pain in insects is not singular and exceptional, it is only another illustration of the law which holds throughout the animal creation, that nothing is given, sense, or power, or function, but what has a certain use. Insects have, in an infinitely higher degree than other animals, certain sensations and instincts which are given to them for special purposes. But when such instincts or sensations, and the capacity for pain amongst them, would be superfluous, or might be injurious, these are withheld.

Take away the painful sensations which come from the skin and its appendages, those attendant on inflammation and those dependent on nervous debility or excitement, all which an insect cannot suffer at all, or only in a very slight degree; take away these, and the chapter of possible insect suffering is reduced within very narrow limits indeed. In a few words, the want of any apparent purpose which could be answered by the presence, and the manifest advantages accruing from the absence, of any high capacity for pain, the inability of the ordinarily sensitive structures to give rise to it in them, and the inadequacy of their nervous system to receive it, all incline strongly to the conclusion that pain, as we understand the word, is not felt by insects.

CHAPTER VI.

ANATOMY AND PHYSIOLOGY.

**ABDOMEN (*continued*). PHYSIOLOGY OF DIGESTION. DIGESTIVE ORGANS.
GLANDULAR SYSTEM. REPRODUCTIVE ORGANS. STING.**

THE digestive and reproductive organs, which occupy the chief space of the abdominal cavity, are, for the most part, fairly open to ordinary observation. Though we may derive the greatest assistance from the labours of preceding anatomists in displaying the details of their structure, yet, in this investigation, we do not find ourselves at once entirely beyond our own resources. And we shall need to take much less on the faith of others' dissections here than in the last chapter.

THE DIGESTIVE ORGANS of Insects deal with the same kind of substances as do those of the higher animals. Their food is reducible to the same classes of aliment, animal or vegetable, nitrogenous or non-nitrogenous, and the same chemical principles are at work in all alike. The difference of the results depends on the different application which is made of the elaborated material, and on the peculiar nature of the animal. This peculiar nature of the animal has a very wide application, for insects of one kind or another seem to eat anything and everything.

The stereotyped answer to the question of what good insects do is, that they destroy other insects. They impregnate flowers, and they do a great many other things which do not concern us just now; but, above all, they consume rubbish and noxious substances. Under the term rubbish and noxious substances many miscellaneous articles are included, wasps, for instance, things laid away in drawers, collections of insects perhaps and the most poisonous drugs. What is one creature's food is another's poison, and the extent to which some of the most virulent poisons are consumed by insects is very singular. Some things which insects eat or drink more particularly greedily are poisonous to them, but, as a rule, it is by substances which reach them through their respiratory organs, rather than by those which they assimilate, that they are destroyed with the greatest facility. The low degree in which the nervous system of insects is developed explains, in a great degree, their immunity from the action of certain of the more deadly poisons. But there is much in this whole subject which we cannot understand, because we cannot fairly examine the subject. We can analyze the ultimate results of some of the processes of digestion, but we cannot follow these processes in detail.

The general principles of digestion in insects, however, may be expressed very briefly, and are plain enough. Thus, speaking with more particular reference to Wasps, the larva is supplied abundantly with food, while its respiration is very imperfect. The same result happens in a wasp's cell as in a pig's sty or a bullock's stall; the food is insufficiently

oxidized, and fat is produced. In the next stage of insect life the respiration is still lower, but, as no food is now supplied, the store of fatty matter is acted on by the oxygen, and is partially used in the formation of the tissues of the future insect. In the last stage, when the insect comes out perfect, the respiratory organs awake from a state of almost inaction to a degree of activity unparalleled in the Vertebrate classes. There is henceforth no production of fat, except under very peculiar circumstances, when, for this purpose, the respiratory process is checked. A familiar instance of this occurs in the economy of the honey-bee, which instinctively suspends the mechanical processes of life, and shuts out the influence of the air, while the sugar in her stomach is being changed into wax. This change, which we can interpret, but cannot imitate in our laboratories, is a simple process of chemical deoxidation.*

With this and a few such like exceptions, the chief end of digestion, in the perfect insect, is to supply materials for the present repair of the muscular system, for the peculiar glandular secretions of the species, and for the substance of the future embryo. The wear and tear of the nervous system, and of the digestive system itself, are comparatively very small items; and that of the skin and bones counts for nothing at all. There is no elaborate system of one gland preparing materials for another; the very simplicity of the whole arrangement baffles our means of research. The whole process is transacted in one vessel, whence the few organs which need it select their own nourishment directly. Bile,

* Honey-sugar = $C_{12} H_{14} O_{14}$. Wax = $C_{80} H_{52} O_2$.

urea, uric acid, and other such like organic compounds, occur as the results of insect digestion, whenever the conditions are analogous to those under which these substances are produced by the higher animals. But analogy scarcely justifies us in the belief that these organic compounds take such an active part in insect digestion as they do in that of the higher animals, either initiating secondary changes, or marking any particular stage in the process. We scarcely know them in insects, except as excretory products.

The anatomical investigation of this system of organs is comparatively easy. Having killed one of the large female wasps with benzol or chloroform, we begin by cutting up the abdominal scales on each side, from the sting to the pedicle, with a fine-pointed pair of scissors. Next fasten the specimen to a loaded cork, under water, by a small pin through the last dorsal scale, and a stronger one through the thorax; keeping the parts just on the stretch. It will be convenient to clip off the legs to prevent their getting in the way. On turning aside the ventral scales which have been cut through, these are seen to be coated internally with a woolly-looking substance. Under the microscope, which should stand at our elbow all the time we are dissecting, this substance is shown to be composed of very fine membranous bags containing collections of minute oil globules. These bags are arranged, in regular order, on the terminal branches of tracheæ, just as the acini of the lobular glands of the higher animals are arranged on their vessels, or like grapes on their

stalks. Besides furnishing a lining to the abdominal scales, dorsal as well as ventral, this woolly-looking substance occurs in the form of detached masses, which are gathered into a kind of omentum overlying the intestinal canal, and filling up all the interspaces of the coils. In the spring the fat masses are comparatively few and small, the nutritive matter having been consumed during hybernation. But in the autumn the young females are loaded with fat, which appears in this form.

The use of these fat masses is obvious. They are an internal supply of nourishment, which the larva prepares and lays up for the pupa or the perfect insect, against such times as they are unable to procure nourishment for themselves from extraneous sources. The pupa lives on this fat, and finds materials in it for the structures which she is developing during her sleep. And the perfect female wasp finds here the sustenance which she cannot go to look for, and she would scarcely find if she did, during her long hybernation. The larva does not need the fat for the purposes of her own existence, for it seems to make no difference to her growth whether the fat be laid up in store or be consumed, as fast as she makes it, by parasites. The common cabbage caterpillar supplies a familiar instance of this robbery of trust-property, so to say. As soon as the caterpillar ceases to make nourishment for the unbidden guests which the ichneumon-fly has inserted beneath her skin, just in fact at the time when she is about to change into a chrysalis, the grubs make their way out of the empty house in all directions, and the "host," previously undistinguishable from other cab-

bage caterpillars, changes, in a few minutes, into a bundle of little yellow cocoons. We need not attribute any great sagacity to the ichneumon grubs. They probably eat the fatty matter, merely because their instinct prefers it, because, in fact, they like it best. They do not touch the "host's" structures till, when she ceases to make fat, there is nothing else to eat, and then, and not till then, they leave her.

The larvæ of the wasps, with which we have here to do, are generally exempt from this particular danger of childhood. Not that wasps and bees, which, with the kindred ichneumons, constitute by far the larger proportion of these parasites, spare their own species, but at least our British Vespidae are pretty free from such attacks.

The use of the fat masses in wasps is such as has been described; they are future food for the insect. In the honey-bee they serve another purpose, as it is from these that the wax is formed; and accordingly they are accumulated in the greatest abundance in the immediate neighbourhood of the ventral scales, just behind the external wax-pockets. The ventral scales of the wasp have little beyond their external marking, to distinguish them from the dorsal, but in the honey-bee there is a great difference between the scales in these two situations. Thus, the ventral scales of the honey-bee are wide, and thick, and clothed with branched hairs at the free edges. They have a strong horny line running down the middle, on either side of which is a thin, seemingly structureless, horny membrane. As the wax plates are of the form and size of this membrane, and of a laminated structure with the cleavage parallel to the

membrane, it is clear that they are formed by transudation through it and not through the connecting membrane, and are moulded on it. They are held in their place by the overlapping of the preceding scale, which makes a pocket divided down the middle by the horny line. And when they are required for use, the bee either shakes them out, or pulls them out with the wax-nippers which are formed on her hind legs between the tibia and first tarsal joint.

Nothing of this kind is seen in wasps: the workers have no considerable accumulation of fat, and the ventral scales, though marked with a dark line down the middle, are not thinned away on either side to a membrane through which the fatty matter could be exuded as wax. Further, their food is not, as a rule, such as wax could be made from, and in short, they do not make wax. Some species of wasps, however, collect honey,* some of the Nectariniæ, for instance, and the allied genus Myrapetra, store up a substance which has been called honey, in spare cells, and so, on a very small scale, does *Polistes gallica*. The substance, when dry, is described as dark brown and hard, quite unlike the usual contents of the cells of a honey-comb, more like jam, a child told me, than honey. By the kindness of Mr. E. Jesse I have been able to examine some of this substance from the cells of a comb of Nectarinia. It was said to have tasted sweet; when I had it the substance was hard, dark-coloured, and evidently consisted of pollen-granules and parts of the petals of flowers, pressed into a mass.

* See Kirby and Spence. 'Introduction to Entomology.' 7th ed. p. 350. De Saussure. 'Monographie des Guêpes Sociales,' p. 232. Wood. 'Homes without Hands,' p. 262.

Now, honey has many things to commend it to house-keeping wasps, but there are difficulties in the way of their collecting it, or storing it, like bees. Wasps have neither tongues to collect it from the flowers, nor proper cells to store it in when collected. The tongue of *Nectarinia* is shorter even than that of our British species, and the cells are no better fitted to keep a fluid in than theirs are, being made, just like those, of paper, lined, if at all, with an old cocoon, and with no other means of closing the top than a paper covering. It is very prudential thus to lay honey by against a time of need, though one would wish the honey were better. But bee-keepers know very well where British wasps get their honey from, and I fear that the foreign species must procure it in the same way, at the expense of the bees. Their stores serve only a temporary purpose, just like bee-bread; for it is not likely that insects whose life is only of a few weeks duration should lay by provisions for a time they are never to see. And I will not say much in praise of honey-making wasps.

As we clear away the fat-masses, the hollow viscera rise up from the cavity of the abdomen, swelled by imbibition of water, to such a size, that one almost wonders how they could ever have been packed away in so small a space. With the fat-masses are tangled threads, some of them tracheæ, others long glandular tubes, which we must take care not entirely to remove, as they are a very important part of the digestive organs. Now, if we lift out the two large air vesicles, which occupy the upper part of the abdominal cavity, on either side, we shall find, concealed, between and behind them, a little pear-shaped

bag. This is the lower end of the oesophagus, dilated into a pouch or crop, which has been also called the sucking-stomach. The last name is ill chosen, for the crop has not any power of self-dilatation by which it can suck: it can only follow the motions of the abdominal walls, like a flaccid bladder. It is merely a receptacle in which the juices on which the wasp lives, or the honey which the bee gathers are collected, not digested. The want of any digestive power is apparent from the structure of the organ. It has no thick glandular lining, and there are few tracheæ on its outer surface. Glands and blood-vessels, or their equivalents, are just as necessary to secretion in the insect as in the Vertebrate economy. In their absence we may safely infer that the contents of the bag are not subjected to any active vital process, but that they are returned from its cavity much as they entered it.

Above, this bag is continuous with the oesophagus, which by gentle traction may be withdrawn from the thorax as a simple tube, of uniform diameter, mainly composed of longitudinal fibres. In the mouth the muscular fibres are marked with transverse striæ, the physiological meaning of which has been already fully explained. But as the pharynx, or throat, narrows into the oesophagus, these are replaced by involuntary fibres, arranged in longitudinal bands. On the walls of the sac which we have been describing, into which the oesophagus gradually expands, the appearance of bands and of distinct muscular fibres is lost; and the sac appears like a membranous bag, with as little power of independent contraction as of dilatation.

The mode of arrangement of the bands which form the muscular coat of the intestines varies according to the requirements of the part. In the oesophagus they affect a longitudinal direction, in the next division of the tube the direction is mainly circular, becoming again longitudinal in the lower bowel.

Outside the muscular is the peritoneal coat, a thin transparent membrane, rarely visible under ordinary circumstances, but occasionally to be traced, when the stomach or intestines are thrown into wrinkles, passing across from fold to fold. A mucous coat lines the whole throughout. This is generally thick and soft, and the changes which the food undergoes in the alimentary canal are mainly effected by its agency. In some insects the mucous membrane is covered, at certain parts, with a fourth layer of a horny nature. This is not found in wasps; but is most perfectly developed in the teeth with which the gizzard of the Orthoptera, instanced in crickets and cockroaches, is armed. These successive layers are the exact counterpart of what we find in the alimentary canal of the Vertebrata. There is a serous, a muscular, and a mucous layer, each extending down the entire length of the capillary intestinal canal, more or less developed severally in different parts according to the function of those parts.

The identity of the serous layer with the peritoneum of the higher animals is questionable; as the peritoneal cavity of insects is rather a collection of vascular sinuses than a simple serous sac. But the muscular and mucous coats are strictly analogous to those of the higher animals. And the horny epithelium of the gizzard of Orthoptera finds its counterpart, both

anatomical and physiological, in the gizzard of birds. Perhaps the insect arrangement is the more complete of the two. For birds have to swallow gravel to assist in the comminution of the refractory particles which have resisted the action of their mandibles; but insects have all the apparatus within themselves.

The crop and gizzard must not be confused together; the one is not a substitute for, nor yet a representative of, the other. They originate in two quite distinct parts, and may co-exist in the same insect. Wasps, like fleas, flies, and butterflies, have no gizzard. Their food is for the most part fluid, and needs no farther breaking up than the mandibles can effect. And the horny lining, which is so highly developed in the cricket, is represented in bees and wasps only by a three-lobed valve which closes the lower orifice of the crop, indenting it like the calyx at the end of a pear.

Resuming, at this point, the description of the successive divisions of the alimentary canal:—the tube here suddenly contracts, and dips down between the two large air-vesicles. Making a half turn in a left-handed spiral, that is to say, in the contrary direction to that in which most shells turn, it re-appears on the surface as the stomach. The physiological importance of this section of the canal is evident, at a glance, from the large number of air-tubes with which it is supplied. Its walls are thick, and thrown into transverse folds; and its general appearance forcibly recalls that of the large intestine of most Vertebrata. As it turns to the left side of the insect, in continuation of the spiral which we have begun to trace, it disappears between the two ovaries, and, narrowing as it goes,

passes behind the left set of egg tubes, which we must divide before we can trace the further course of the canal.

As we now draw the stomach gently forwards, gradually tearing away the fine tracheæ which closely surround and retain it in its place, a yellowish flocculent mass comes into view, chiefly composed of threads at once distinguishable from the white air tubes with which they are entwined. These yellow threads are a system of gland-tubes, which enter the alimentary canal at the line of demarcation between the stomach and the small intestine. The line is a little wider and less definite in the wasp than in the honey-bee, but in both equally it indicates the point where the canal changes its functions, where the stomach ends and the small intestine begins. Probably we shall break the alimentary canal of a good many wasps, at this delicate point, before we succeed in obtaining a specimen of the tube, perfect and continuous in its entire length. For not only is it very soft here and easily torn, but this is one of the narrowest points in the whole intestinal tract. From the extreme narrowness of the passage here, at the outlet of the stomach, it would seem that very little of what is taken into the stomach is intended to pass through it undigested. The economy of the larvæ of the wasp differs, however, materially from that of the perfect insects in this respect, hard indigestible matters forming, as we shall see presently, an appreciable proportion of the food with which they are supplied by their nurses. But, if the wasp's mandibles are not adapted to grind hard substances into a pulp, wasps have a most effectual protection against any large masses, which might

cause trouble farther down the canal, ever getting into the stomach at all. With the close fitting valve at its entrance, and the free power of emptying the crop by aid of the air vesicles, their stomach is pretty safe from having anything passed into it which cannot pass out of it.

Some of the tangled threads which we tear through are air tubes, distinguished, even to their minutest ramifications, by their white colour and the presence of a spiral fibre wound round them. In the yellow threads we recognize another elementary tissue. These are gland tubes; they are opaque and finely granular, and, from their analogous position, have been thought by many to represent the biliary vessels of the higher animals. Referring again to Van der Hoeven's admirable summary* of the latest—as far as I know—discoveries in insect anatomy and physiology, we find reasons for hesitating to accept this opinion without qualification. The economy of insects is so very different from that of the Vertebrata, that we are not justified in inferring, from mere analogy of position, as to the functions of any organ. The discovery of uric acid in the secretion of these yellow gland-tubes has led some to infer that they represent the kidneys rather than, or as well as, the liver. But, in truth, the present state of our knowledge scarcely justifies any definite conclusion on this matter.†

* Op. cit., p. 256.

† The excretions of insects have been made the subject of special examination by Dr. John Davy. Wasps have come in for their share of attention, and uric acid and urate of ammonia are set down as constituents of the excretions of the perfect insect and the larva respectively. 'Trans. Entomolog. Society.' Vol. III., N.S. 1854-56, p. 18. I have often failed to find uric acid in these excretions,

Insect glands, with few exceptions, of which the salivary glands of the wasp are perhaps the one most familiarly known, are constructed, or, better perhaps, are arranged, in a tubular form. The glandular element, consisting here, as in the higher animals, of epithelial cells, is placed within the tube, and their secretion is poured out from its open end. In the particular instance before us, no better or simpler means to gain the object in view, under all the circumstances, could be devised. The long capillary tubes float free, by the side of the tracheæ in the fluid on which they are designed to act, and the products of their operations are poured directly into the alimentary canal. Much of the ordinary glandular system, and the whole lymphatic system are thus dispensed with in the wasp's economy.

By very careful manipulation, with the forceps and dissecting needle, this tangled mass of gland tubes and tracheæ may be removed, leaving the small intestine quite clear, as a tube of much smaller calibre and much less strength than, though otherwise bearing a general resemblance to, the stomach. It lies deep, at the back of the abdominal cavity, behind the left ovary, carrying the spiral coil which we have been tracing still farther downwards and to the left. It is separated from the next following section, the colon, by a line of demarcation yet more distinct than that which separates it from the stomach. Thus;—it contracts rapidly to a narrow point, which indents the

though the food happened to be the same as in the instances where I had found it present. It was absent from the contents of the distended colon of Ligurian bees dying of an epidemic disease. It was present in large quantity in the excretions of a leaf-cutter bee.

head of the colon, and appears as a nipple-like projection in its interior, forming a valvular constriction at this point. As the valve at the bottom of the crop was set to prevent substances passing involuntarily onwards into the stomach, so this is set, like the valve at the top of our own colon, to prevent substances regurgitating under pressure, from the large, back again into the small, intestine. It may be shown most plainly under the microscope by black back-ground illumination.

The insect economy is so different from that of the more familiar subjects of physiological observation, that it would be unsafe to draw any more than general inferences from the higher animals as to the nature of the changes in the food which are effected in insects by each separate section of the alimentary canal. The distinct functions, however, of the large and small intestine of the wasp are easy to be recognized in their structure. The glandular element predominates in one, and the muscular element in the other; pointing to an important difference in their operations. The colon has not nearly so abundant a supply of air tubes and glands, or glandular appendages, as the small intestine has. It is larger, and evidently mechanically stronger; the annular folds of the mucous membrane of the small intestines being here replaced by longitudinal folds, in which the greater development of the muscular coat is apparent. But the functions of this part of the bowel are not exclusively mechanical. The fluid, which was necessary to float the refuse of the food and the excretory matter through the narrow intestinal or glandular passages, is here re-

absorbed into the system. If the fluid enters faster than it can be strained off, the colon may become greatly distended. And to equalize the pressure, to allow of very considerable expansion without risk of laceration of the bowel, six horny bands are inserted into its walls longitudinally.

These horny slips mark the limits of the colon; below them the canal contracts at once into a strong, straight tube—the rectum. Its functions are merely to expel from the body what can be of no further use to it, namely the substances from which all nutritive matter has been extracted; and the excretory results of the daily wear and tear of insect life. Purely mechanical in its functions, its structure presents the simplest mechanical arrangements. In the higher animals a circular muscle, called a sphincter, surrounds the opening of the bowel and secures a voluntary control over the evacuations. In the wasp the same object is attained by a different contrivance. The open end of the bowel—referring now to the female wasps—is attached to the base of a triangular horny scale, called the vent-cover. This generally stands at right angles to the canal, stopping the passage as effectually as a clip on a bent India-rubber tube does. But, at the will of the insect, the vent cover can be drawn into a straight line with the canal. There is no resistance from an opposing sphincter to be overcome, nor is any co-ordination of movements required; but, by the most simple arrangement, the same movement which opens the passage expels the contents of the bowel.

The whole length of the canal coiled away in the abdomen of a healthy female wasp may be reckoned

at about thirty lines. But this measure must be accepted only as a very rude approximation, on account of the yielding nature of the tube, which may be stretched to various lengths by different observers. The spiral makes about two complete turns in its passage through the abdomen. Speaking of insects generally, the length of the alimentary canal varies in each family inversely as the digestible nature of their food. Predaceous insects, that is to say those which live on animal food, have, as a rule, shorter alimentary canals than vegetable feeders, because, as a rule, their food is more easily digested. But this rule has numerous exceptions. If the food be easy of assimilation, whatever its nature, animal or vegetable, the canal is short and simple, but if it be more refractory the canal is longer, and its appendages are more complex. The food of the wasp, though mixed, is generally fluid and easy of digestion, and the alimentary canal of the wasp, accordingly, as we have traced it, is short and simple.*

THE REPRODUCTIVE SYSTEM comes next under consideration. There is no great difficulty in the anatomical examination of these parts, none but what patience and practice will surmount. The several organs are large enough to be easily recognized, when we have once learned where to look for them, and how to disentangle them. It is in the morphological interpretation of what we see that the chief difficulty and the great interest of the inquiry lie. I must refer to Burmeister's elaborate

* See this question fully examined and illustrated, 'Cyclop. Anat. Phys.' Vol. II, pp. 966—973.

work * for a fuller and more comprehensive account of this system, both anatomical and physiological, than I could find room for here. But, without entering into all the details, which belong to entomology generally rather than to our present subject, it will be necessary, to the full understanding of the natural history of wasps, to give more than a cursory sketch of these organs; the female, so important in a physiological point of view; the male supplying the most unfailing anatomical distinctions between different species.

It will facilitate our examination to bear in mind that there is a certain correspondence between the several organs in the two sexes respectively. Not that each organ has its exact counterpart in the other sex, but that the chief organs are evidently framed on a type common to them both. This community of type displays itself in the form and elementary structure of various parts whose functions may be very dissimilar. The clue fails us when we deal with parts which have no essential character by which we may discover them under another form. But where any such characters are present the morphological identity of these parts may be certainly proved. And the analysis, though it has been less studied, has no greater difficulties than, and is as full of interest to the anatomist as, that of the thorax.

The male organs of the wasp, as of other insects, consist of two symmetrical secreting glands, the testes, and an intromittent organ. It is in the

* 'Entomology, translated,' pp. 181—223.

various forms which this last assumes that the specific distinctive characters are found. By this means the distinction between *V. germanica* and *V. vulgaris*, which the external markings of the two species often fail to give, has been established.* This organ consists of a horny case which occupies the end of the abdomen. It is formed of two valves opening along the middle line with a horizontal expanding movement very like that of the bivalve specula which Surgeons use for examining internal organs. The groove below is accommodated to the central spine, while the upper one receives the rectum. The form of the vent-cover is adapted to the sex of the insect. Instead of a scale being laid half-round the bowel, the bowel pierces the scale obliquely, and the same end is accomplished by, if possible, a still more simple mechanism than has been described in the female. The outer pair of valves end by a sharp, and more or less recurved point, which in *Odynerus* projects considerably beyond the end of the abdomen. Within, connected with the outer valves, lie a smaller pair of horny valves, which end, not in a hook, but in a filament which is clothed with fine hairs. These filaments lie parallel to each other and to the intromittent organ which is placed just beneath them. They re-appear in the caudal palpi of the female in a larger and more distinct form. The end of the intromittent organ comes fully into view on their removal. Spoon-shaped in *V. vulgaris*, bifid in *V. germanica*, the various forms which it assumes in different species are easy of recognition

* Smith's 'Catalogue of British Fossorial Hymenoptera.' &c. 1858. Plate V, Figs. 20 and 21.

with a common lens, and unfailing in their application. To the central spine which supports this we shall return, further on, in the female, where it appears in the modified form of the sting.

The testes are placed symmetrically, deep within the body. They correspond to the symmetrical ovaries of the female, not only in their general outline, but in the tubular arrangement of their internal structure. Like them, too, they run off into tracheal threads at the anterior extremity. Hunter* says that, while these glands are developed on both sides in the hornet, in the wasp usually only one is found. I have never examined these organs in a hornet; but in wasps I have generally found two glands, placed symmetrically, occasionally varying in size, and sometimes having tubular diverticula, or lateral pouches.

The male organs are obtained for dissection with very little trouble. The wasp, as fresh as possible, should be gently pressed on the abdomen, and, as the strong horny scales protrude, they may be withdrawn by the aid of the forceps, bringing with them the testes and the end of the alimentary canal. The appearance of the specimen is not in any way injured by the careful removal of the organs in this manner. For a more particular examination, however, they must be removed from the abdomen in the same way as, and, on account of the smaller size of the male, with even greater precautions than, the organs of the female, which come next under consideration.

For their demonstration we need the water-trough,

* Hunter. Posthumous Works 'On the Economy of Hornets and Wasps.' Vol. I, pp. 79 and 90.

and, if we can procure one, a dissecting microscope. We begin by removing the stomach with great care, dividing it where it dips down between the ovaries. The central air-trunk should then be cut through, as near the pedicle as possible, and gently drawn on, clearing away the tracheæ the while, till the egg tubes come into view. The whole mass may now be withdrawn, with a portion of the colon, in connection with the two last dorsal scales. We should procure as many of these ends of wasps as we can, and set them aside in glycerine. For the dissection is long, and we shall probably need a good many specimens before we succeed in fairly displaying all the parts.

Now, placing one of these fragments in a watch-glass full of water, steadied on an India-rubber ring, if we carefully remove the dorsal scales, and the sting with its bulb, we shall readily distinguish the two bundles of egg tubes. These converge at one end to an air trunk, at the other to a single membranous canal; from which point we may most conveniently begin their description. This canal is called the uterus or oviduct, the latter name perhaps being the most correct, as it resembles in its functions the oviduct of birds rather than the uterus of Mammalia. Tracing this backwards from the point where it emerges from the muscular bulb of the sting, the first object which attracts notice is a little oval vesicle, distinguishable at once from the round, hard poison bag by its much smaller size and greater softness. It stands at right angles to a short tube, by which it communicates with the upper side of the oviduct. From its other end arise two small tubular glands. This is the spermatotheca, designed, as its

name implies, to contain the fertilizing fluid with which each egg is brought into contact as it passes down the oviduct.

During this examination the eye may perhaps have been caught by a clear white glittering thread, connected rather with the root of the sting, as it might seem, than with the uterus. This is the gluten gland. It is the source of the glutinous secretion which coats the egg just before its final extrusion and, hardening into a skin like that which invests the eggs of snakes, fastens it to the cell wall. It is a clear transparent tube, distinguished from other gland tubes by not being marked by the presence of cells within it, and also by its much larger size. It is found without difficulty, if the mass of sting and uterus be carefully torn up under the microscope; its bright opalescent appearance readily distinguishing it from the loose white shreds in which it lies entangled. But as it is very soft, it is liable to be separated from its connections. It is about a tenth of an inch or more in length, sometimes bifid at the free end; of irregular outline, about one eightieth of an inch in diameter at its widest part, but narrowing towards its orifice. It opens in the middle line, on the lower wall of the uterus, at the point where this joins the common vent or cloaca.

It should be observed that the dissection of all these parts is much more difficult in the wasp than in the honey-bee, where they are larger and firmer, and altogether much better developed. Indeed, the small wasps are far behind their larger sister, the hornet, in this particular. However, queen-wasps are much more common than queen-hornets, and

much more easily procured than queen-bees, and what we cannot display in one specimen we may find in another, with leisure and patience.

Glands, tubes, and membranes, in their elementary forms, are of such universal occurrence, and are structures of such plasticity of development, that organs composed of these materials admit of great variety of form, and occur—are improvised—almost anywhere. Such are the simple appendages to the oviduct which we have just been tracing. They are mere appendages to what is itself merely the duct of another organ. The materials of which they are made are not peculiar to the parts, for they are found everywhere; it is their plasticity that is peculiar, their power of adaptation to all the minutiae of local requirements. This very power tells us not to expect to find identity of form here in the two sexes respectively; and least of all in parts where the correspondence is essentially one not of uniformity but of reciprocity.

In the ovaries however we see, at once, that we are dealing with a more important structure, and the analogy to the testes of the male is complete, both in internal structure and in external conformation and relations. Just, in fact, as in the higher animals. As we follow the uterus, or, in accordance with these views of its functions, the oviduct backwards, we observe that it divides into two horns. These are again each subdivided into six egg-



Fig. 10.—Uterus, ovaries, and spermatheca of a pregnant female.

tubes, which are called, collectively, the ovaries of either side, and are filled with eggs in different stages of development. The eggs which lie nearest the uterine end of the tubes are much more advanced than those farther in. As we follow the tubes inwards the eggs are found to be smaller, harder, and of a whiter colour. Hunter* counted fifty eggs, though with some difficulty, in one of the twelve egg-tubes of a hornet. I have never counted more than seventy eggs, rudimentary or well-developed, in the entire ovaries of a wasp; rarely more than half that number. While the ovaries of the female honey-bee contain more than ten times as many.† My observations were mostly made on wasps taken in the early summer, and of course this number did not represent all the wasps which were to be developed in the course of the season, but only so many eggs or germs as were sufficiently advanced at that time to be visible. Still, making all allowances, the fertility of wasps is really much inferior to that of the honey-bee. Not only are the eggs fewer, but the egg-tubes are much fewer. And the difference is apparent at whatever period the examination of the ovaries be made, whether they have been taken from the queen-mother of a thriving swarm in July, or from the strong-minded female who has to be servant-of-all-work to the infant swarm in May or June.

The organs, which have been just traced in the perfect female, may be found in a more or less imperfect form in nearly all the workers, which are, in fact,

* 'Posthumous Works,' by Owen. Vol. I, p. 80.

† See Swammerdam. 'Bybel des Natuure.' Tab. XIX, Fig. 3. Folio Ed.; also Rymer Jones. 'Animal Kingdom,' Fig. 127, p. 283.

imperfect females. We owe the discovery of the female sex of the workers of the honey-bee to Mademoiselle Jurine.* Not to anticipate here what there will be occasion to discuss fully at a later period, I would only add that the rudimentary female organs are usually much less perfectly developed, and found, accordingly, with much greater difficulty in the worker-bee than in the worker-wasp.

To the general reader the part of these organs that has the greatest interest is unquestionably the sting. In the higher animals, with the exception of many birds and some beasts of prey, the male is most commonly the more powerful of the two sexes, and wears the offensive armour. But in insects, as in spiders, this order is generally reversed; and, with the care of the young, which devolves on the female, is given the means of protecting them. Aristotle† has a singular remark that, "insects with four wings are distinguished by their greater size or a caudal sting. The Diptera are either such as are small, or have a sting in their head." In both these classes alike it is the female which carries the weapon; not only in the Hymenoptera, where the sting consists of a portion of the male organs in a transformed state, but in the Diptera, where the biting instrument is common to both sexes. Fleas know no such distinction, and the male seems to bite worse than the

* I have no more direct authority at hand to refer to for this statement than the note in Van Der Hoeven's 'Handbook,' Vol. I, p. 271, with references to Huber, 'Nouv. Observ. sur les Abeilles.'

† Aristotle's 'History of Animals,' transl. by Cresswell, p. 8, Book I. chap. V, § 5.

female; besides, from his smaller size, and from his never being encumbered with the internal burden of a family, being much harder to catch. But it is the female mosquito and the female horse-fly only which bite.

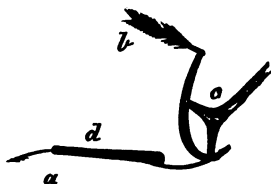
To procure a sting and all its appendages for examination, the best way is, as before, to press the abdomen of a recent specimen till the sting, and the muscular bulb to which it is attached, protude. Now, grasp the sting at its root with a pair of forceps, and draw it gently out, still keeping up the pressure. By this means we may secure the sting, the bulbous mass which moves it, and the poison bag, all together. As with regard to the ovaries, it is best to secure as many specimens of stings, and of as large a size, as we can, and set them aside in glycerine against a leisure afternoon. They will need, however, very little dissection. Under a low power of the microscope, brightly illuminated on a black back-ground, the chief anatomical characters will be readily made out.

And first of the sting itself. This consists of two very fine triangular bristles, presenting on the outer side a sharp edge finely serrated at the point, and on the inner side a flat channelled surface, where they lie in juxta-position, along the middle line, like two bayonets laid together. These are the barbs. The scabbard, in which they slide, is a flat horny piece of considerable strength which most people, without a microscope, would take for the sting. It is connected at its inner end with the muscular bulb, and has its edges turned over to form guides for the barbs. It is nearly straight in the workers, but strongly curved in the females, and tapers towards its free end. The

curved form of the scabbard gives the barbs a certain amount of elasticity, without which such delicate instruments could scarcely be driven into any hard substance, while the fact of its tapering keeps the barbs close together at their points. Within the body, where they no longer need the protection of the scabbard, the barbs leave the groove and, still diverging from each other, bend round either side of the muscular bulb till they end by being articulated at right angles to a strong horny limb or lever, which gives attachment to powerful muscles. By a rapid alternate movement of these levers the barbs are driven into the wound, the teeth of one barb acting as a fulcrum for the other. The two channelled surfaces on the inner side of the barbs are pressed firmly against each other, so as to form a closed tube between them, down which, with all the force the muscular walls of the poison bag can exert, the venom is injected quite to the bottom of the wound.

Fig. 11.—Diagram of the mechanism of the sting.

a, one of the barbs passing in the guide, *d*, to the lever, *c*, which works at the same time on the feeler, *b*.



The poison bag, which is readily recognizable as a hard roundish white body, is a strong hollow muscle made in four segments, like a foot-ball, the fibres of each segment meeting those of the adjoining ones at an acute angle. At one end of this bag, two long glands may be observed, which secrete the poison. From the opposite end issues a long, strong duct, which conveys the poison from the interior of the bag

to the root of the scabbard, where it opens close by the channel in the barbs. The honey-bee's sting has a very similar arrangement, with only one poison gland much longer, however, than the wasp's, and bifurcated at the extremity. Conversely their poison duct is much shorter than that of the wasp. And the bee has less power of withdrawing her sting than the wasp, so that the act of stinging more often proves fatal to these irritable little creatures, which leave both sting and muscular bulb sticking on the hand or glove which has offended them.

The nature of the fluid which, in so minute quantity, causes such excessive pain, is probably not to be determined by chemical analysis, even could we obtain enough of it for this purpose. To litmus-paper it gives a very strong acid reaction, but the pain which follows its introduction into the skin is much greater than a drop of even a highly corrosive acid would cause; and, unfortunately, alkalies are not always a specific cure for its disagreeable effects. The second bite of a snake is said to be less deadly than the first, from the gland having exhausted itself. But as a wasp or bee stings away, for as long as the sting itself lasts, each prick is as sharp as the one before. And judging from the quantity which distils on pressure from the point of the sting there seems to be poison enough to infect all the wounds.

The muscular bulb is a flattened, somewhat oval body, like a seed enveloped in a horny testa. This skin or testa is really a skeleton, corresponding to the outer valves of the male organs, formed of several pieces, and giving attachment to the various muscles which enter into the composition of this delicate and

elaborate piece of mechanism. It is framed in two symmetrical halves, which are united in the middle line. Between the two segments, in the looser tissue, a passage is found for the poison duct, the oviduct, and the termination of the alimentary canal, arranged in this order. The poison duct lies lowest, just above the scabbard which, besides its other use, serves to bind the two segments of the bulb firmly together along their lower edge. On the upper edge of the bulb, and half encircling it, a kind of saddle is loosely applied. This is the seventh dorsal scale of the abdomen, the twelfth larval segment. Its real nature is obvious, from the spiracles and tracheæ which we can trace on it. In the male this saddle is not found here, but appears as an external dorsal scale, adding so much to the length of the abdomen in this sex.

Just beneath this diminutive scale lies the end of the alimentary canal, with its vent-cover as already described. The orifice by which the alimentary canal opens externally is almost common to it and to the oviduct, as in birds; the two tubes being separated only by a thin membrane. The edge of this membrane is marked by a tubercle from which a pair of palpi or feelers spring. These are not flexible and jointed like the palpi of the mouth, but straight, and covered on the outer side with fine hairs. When at rest they lie beneath the bulb, parallel to the sting, which lies between and below them, pointing the different way. But, as we press the abdomen and the bulb protrudes, they diverge from the sting and from each other. As the bulb revolves on its axis they point upwards, and the sting, ready to strike, points downwards. Their use may be conjectured, in the absence of direct

observation, from their position and connections. As they are set in motion by the same levers which protrude the sting, it might seem, at first, as if they were connected with its functions.* But their employment must rather alternate than coincide with that of the sting; because the action that protrudes the one, withdraws the other organ. They might possibly act as feelers and guides to direct where the sting should be applied; but the sting seems to need no such guidance; and, as the fact, they are not put out as a preliminary to stinging. I believe them rather to be employed in oviposition, to receive the egg from the oviduct and to fix it to the wall of the cell.

* Hunter. 'Posthumous Works.' Vol. I, p. 80, takes this view of their use. But, on the grounds assigned in the text, I believe it to be erroneous.

CHAPTER VII.

FORM AND MODE OF CONSTRUCTION OF THE NEST.

GROWTH OF THE NEST. INTERNAL ARRANGEMENTS. WASP-PAPER. END
OF THE NEST. ARCHITECTURE OF THE SEVERAL SPECIES.

IN the first room of the Northern Zoological Gallery of the British Museum is a beautiful collection of the nests of insects, which has grown up under the care of Mr. F. Smith, during the few last years. Many of these nests have been described and figured in "Homes without Hands." And Mr. Wood's interesting volume affords an excellent introduction to the treasures of this room. It is only with the wasps' nests that we have here to do, but, in this department alone, there is occupation for hours, in the examination of the wonderful contents of the wall-cases.

No insect probably has a more versatile talent for building than the wasp. In these cabinets we may trace all gradations of texture, from the flimsiest lace work, which must not be touched by unwary hands, to the cardboard box, which might lie about the nursery without damage. Brittle mud, and tough fibre, all alike, each in their turn, are put in requisition by these little architects. *Chartergus* hides her cells with a cover which needs a knife to get

through it; *Polistes*, with many others, makes no cover at all. As a rule the combs of wasps are placed horizontally, but *Nectarinia* builds her's in concentric segments of a sphere. Strength and attention to mechanical considerations mark most of the nests, but *Icaria* builds out into space quite regardless of these. *Synæca* spreads a smooth polished roof over her single stage of cells, which she boldly hangs out from a bough, while *Polybia* seeks the protection of a large leaf, or of the back of a tree to cover the mouths of the cells. In most instances the rain-drip is carefully provided against, and the surface is freed from all needless points, but *Myrapetra* covers her house with tubercles whose object is quite inexplicable. Each has its own fixed rule.* Whether the surface be smooth or rough, whether the entrance be central or lateral, whatever the habit be, the habit is unvarying, and the style of architecture in all its details is absolutely typical of the insect, as typical as the Phœnician bevel or the Norman mouldings. So I make no apology for devoting a whole chapter to the consideration of the architecture of the comb and the case of our British *Vespa* in all its typical exactness.

With the first promise of Spring, with the violet and the primrose, with the snake and the bee, on the same bank, from which the warmth of the sun has called them all forth, the mother wasp enters on active life. During the cold wet winter months she

* De Saussure, op. cit., and Möbius, 'Die Nester der geselligen Wespen,' 4to, Hamburg, 1856, have made the mode of construction of the nest the basis of a system of classification of Social Wasps.

has sheltered herself as she best might in dry banks or old walls, in the folds of curtains or in the toes of shoes laid by, like herself, for the season. And if, by chance, she has been disturbed from her hiding place, dusty, half torpid, she has seemed more like an out-cast from the old nest than the future mother of a colony. But all this is altered now, and as she flies quietly along, examining each crevice in quest of a proper place to build her nest in, the eye of the gardener recognizes in her no helpless wanderer seeking a hiding place, but an instrument of destruction which he will do well to crush in the bud.

These large female wasps, these future queens just entering on active life have, however, yet a very trying time to pass through. Besides the little boys who are stimulated by a bribe of so much a head to catch and kill them for the gardener, there are other, yet more persistent, if not more active enemies. What with late frosts, and rains, and birds, and little boys, comparatively few of the wasps which have lived through the winter survive to become the mothers of colonies. For, through all these weeks she is alone and unaided, with a home to find, a nest to build, and then the hungry grubs to feed. And all this when food is scarce, and the sun's warmth, that first necessary of life to a wasp, so very uncertain.

When, at last, the wanderings of the future queen have come to an end, and she has found a hole or a branch to suit her fastidious taste, she enters, in earnest, on the work of her life. The first rudiments of the nest that is to be appear in the form of a little grey cap of a flattened conical form, from half an inch to an inch wide, hanging from a footstalk.

Above the cap this footstalk spreads out into a flattened triangular strap, by the edge of which it is fastened to a branch or a root. Below it is rounded into a cord which affords support to the rudiments of three or four little cells—I have always found four—not yet built up to their full height. Each of these already contains an egg, which, as the opening of the cell is directed downwards, is firmly glued in its place. This is the first beginning of the nest. Other cells are soon added, and the cap or cup covering and surrounding them is thickened by successive sheets of paper, which are laid on the outside and carried down from the footstalk to the bottom, overlapping the edges of the subjacent layers. Unnoticed by all but very inquiring eyes, against the grey background of a tree or a hedge-bank, these little fairy cups, about as big as a pigeon's egg, may be found in turf-heaps, or under eaves or branches, or are turned up by the plough. They are the sole work of the queen wasp who, alone and without help, builds up the cells as the larvæ grow, and adds layer upon layer to the outer case, till the young brood, on whom the duties of enlarging the nest and tending the young are presently to devolve, come forth from their cells.

These little nests may be found, at all seasons of the year, dusty and deserted, hanging from eaves or in out-houses. The queen-mother has fallen victim to one or other of the many dangers to which she is exposed, and the nest is abandoned. Caprice, too, seems sometimes to cause a wasp to desert a nest only just begun. But, in a few weeks, the safety of the structure is made independent of

the chances of a single life, And as the nest grows, day by day, from this little fairy ball which might be hid in an egg-cup, to a great paper city, which the most determined naturalist will think twice before he attacks, the characteristics of the different species are impressed on the work. But, in the first instance, they are not very obvious. Leaving, therefore, for the present, these specific distinctions, let us here trace, in the general description of a wasp's nest, what all the species have in common.

All the embryo nests of British wasps which I have seen were constructed on the same plan. There is in them all a thin pedicle springing from a triangular strap of paper, and there are successive coverings unconnected with each other, larger and more numerous as the work increases in dimensions, and turned in below so as to close the nest at the bottom. When the nest has once been closed, henceforth all its further enlargement is made on the same plan. Though new combs are being constantly suspended, one from and under another, and the old ones are constantly being added to at their edges, yet the nest always maintains its original form. And all the while that the four primal cells are growing into eight or nine combs six inches or more, perhaps, in width, the nest cover still remains, throughout the process, round, and shapely, and perfectly closed; excepting, of course, the single entrance hole. This progressive enlargement involves a greater expenditure of labour and material than would have been required if the nest could have been laid out in the first instance on a larger scale. However, as it is absolutely necessary for the protection of the brood that the

bottom of the nest should be kept constantly closed, and labour as well as material is abundant, it is applied unsparingly. As the comb grows, day by day, still wider and wider, the inside of the case is cut away to make room for it; and the paper which is removed on the inside is replaced by new layers on the outer surface. So that all the space enclosed in a wasp's nest is occupied twice, first by layers of paper in the gradual expansion of the case, and ultimately by comb. The quantity of material consumed in the construction of a large nest must be very great, for, as a rule, the waste cuttings are not employed again. To a certain extent the paper which has been used once may be again available, as a source of material; but it is never transferred from one part of the structure to another without being nibbled down and worked up into pulp, as in the first instance. The floor under a swarm of working wasps is strewn with scraps of waste paper, as thickly as the floor of a bee-hive is with waste wax plates. Not unfrequently wasps will avail themselves of neighbouring leaves to work into their nests, and some foreign genera* make the cover of their nest of a large leaf. But wasp-paper is never removed and re-applied in bulk, any more than the material of which bees make their cells.

We must not measure the proceedings of wasps by the same rule which we apply to a man with a taste for building, who gradually expands a cottage, at the cost of much useless labour, and with great

* *Polybia sedula*, figured by De Saussure. 'Guêpes Sociales,' Pl. XXI. *Leipomeles lamellaria*, Möbius. 'Die Nester der Geselligen Wespen.' Taf. XVII, und anders. 4to. Hamburg. 1856.

waste of money, into an ugly, inconvenient house. For labour is the lot and pleasure of the wasp, who must and will work, so long as she has a nest, while the sun shines. And waste, in the sense of consuming as much rotten wood as possible, is one of the chief objects of her existence.

The details of the process of construction are the same in all our British Vespidae, under all circumstances. Tree-wasps and ground-wasps, whether they use grass-fibres, or rotten-wood, or paper-cuttings, work up the material in precisely the same manner, and lay it on according to the same teachings of their common instinct. Stand quietly on the sunny side of a row of palings on a summer morning, and you may observe the first step in the process of building a nest. Here will be found wasps of all the species in the neighbourhood, hard at work collecting materials for their nests. Wasps may easily be taken while thus engaged, in a gloved hand or a handkerchief, and the pellet which they hold between their mandibles will be found, on examination by the microscope, to be identical in composition with the substance of which their nests are made. But the wood-scrapings which they come to gather off any old gate or posts, with such indifference to danger, are not by any means the only, nor indeed the chief materials employed by most species. Round the swampy edges of ponds, or in wet ditches, or on the downy leaves of plants, wasps may be seen gathering tough herbaceous filaments which they felt up into a texture stronger and better able to resist the wind and rain than a paper made of wood-scrapings. Only

a wet ditch is not a very comfortable place to wait in, and wasps are more easily watched and caught on a smooth rail than on a bramble bush.

Now, transferring our post of observation from the collecting ground to the nest itself, we may see the mode of applying these materials. But it is not so easy to find a tree-nest, where the work is open to observation, just when we want it. A friend tells me that the grocers' boys at Bexhill amuse themselves by *lining* wasps to their nests, just as the North-American Indians line bees. I never had any practice in this sport. It is not very easy, particularly out of doors, to slip a noose round a wasp's pedicle, and fasten a tuft of cotton-wool to it, without hurting her. And where I have done this, in my study, the wasps have been unable to rise, thus hampered. The best way, to my own experience, is to watch for more than one wasp flying quick and straight in the same track. A few minutes' observation will settle whether there is a wasp's nest in the neighbourhood. The process however is tedious, for the same amount of skill and patience is required to find wasps' nests, when we want them, as to find fish, or anything else. And folks who do not love wasps will often have occasion to rejoice because no nests have been found after a morning's search.

But when we, or, what is more likely, some hedgecutters for us, have found a tree-nest, we may carry on our observations a stage further. A somewhat cloudy day, with little or no wind, is the best for this purpose. The wasps may not be working so vigorously, but they will allow us to approach more closely under such circumstances, and they, as well

as we ourselves in consequence, are less liable to sudden interruption from the wind shaking the nest. It is easy to recognize the wasps coming home laden with building materials. We may see, at a glance, the out-stretched neck with the pellet of gatherings between and beneath the mandibles. I have watched the process of paper-making very closely in two nests of different species which I had for some time in a case on the window ledge. By putting distinctive marks on the back of the thorax of several wasps, some curious information was obtained as to their habits of building. It appeared that when a wasp came home laden with building materials she did not immediately apply these, but flew into the nest for about half a minute, for what purpose I could not ascertain. Then emerging she promptly set to work. Mounted astride on the edge of one of the covering sheets, she pressed her pellet firmly down with her fore-legs till it adhered to the edge, and, walking backwards, continued this same process of pressing and kneading till the pellet was used up, and her track was marked by a short dark cord lying along the thin edge to which she had fastened it. Then she ran forwards, and, as she returned again backwards over the same ground, she drew the cord through her mandibles, repeating this process two or three times till it was flattened out into a little strip or ribbon of paper, which only needed drying to be undistinguishable from the rest of the sheet to which it had been attached. And then she gravely retired into the nest again.

By this means of marking different wasps, it was evident that each wasp had not a place of her own

to work at, but that they all worked anywhere and anyhow. And this, whether they were engaged in adding to the structure, or in removing what had been built previously. So, a wasp which had been collecting white fibres joined her quota to what had been built by a wasp which had gathered materials of a darker colour, giving a variegated appearance to the work. Further, it seemed clear that only the young wasps built, probably because they only had the power of secreting mucus in sufficient quantity for working up the dry fibres into a pulp. This was inferred from the generally larger size, and the smooth ends of the wings, of the wasps which were examined while thus engaged. Wasps grow smaller as they grow older, and the ends of their wings get tattered with advancing days.

Marking a wasp is an operation requiring a little skill. Pastor Müller* used to put a little colour on the antennæ of his tame hornets; but this plan admits of very little variety in the marks. First catch your wasp. Réaumur† used to catch his by means of a stick tipped with some glutinous matter; but to this mode of proceeding there are obvious objections, particularly on the part of the wasp. I prefer a glass tube, about twelve inches long by three-eighths of an inch wide. This should be joined, by a piece of India-rubber tubing, to a mouth-piece, and be stopped at this end by a few turns of fine wire, loosely packed, so as to let the air pass freely, but to catch the wasp as it is drawn in. With this

* Müller, 'Beiträge zur Naturgeschichte der grossen Hornisse,' op. sup. cit.

† Réaumur. 'Memoires pour servir à l'Histoire des Insectes.'

instrument, with a little practice, any wasp, even the sentinel herself, may be picked up without causing a commotion. Once within the draught of the tube, the wasp flies up to the stop in a moment. It remains only to blow her down very gently, and catch her in gloved fingers. Then, with white paint, a circle, a cross, a line, or any number of dots, may be made on the mesothorax, out of reach of the wings, lest these should get smeared and clogged. When this has been effected, the wasp's departure may be speeded by a puff from the tube, before she can avenge herself for the treatment she has received.

By the conjoint labours of all these busy workers, here a little and there a little, the nest grows. The work of one week may have to be removed the next week, to make way for modern improvements and for the requirements of the growing city; and, as we have seen, it has nearly all to be done twice over. But wasps work very hard, and the nest grows visibly day by day. The little egg-shell in which it began is lost in the changes which the top of the nest undergoes. The slight strap from which it hung is now quite inadequate to sustain the daily increasing weight, and new points of attachment are sought to projecting roots, or stones, or branches. Sometimes a branch runs all through a nest, materially adding to the difficulty of its capture. Or, failing these, the original point of support is strengthened by layer upon layer of paper, rubbed smooth, and thickly coated with wasp-gum, to preserve so vital a point from all accidents of wind and weather.

The regular arrangement of the upper part of the nest is much disturbed in the course of these events, and the top of one nest comes to look very like the top of another. But, at the bottom, at the growing part of the nest, the different architectural instincts of the several species are displayed quite to the last. The number of layers of paper employed to form the nest-cover varies with the species, with the season, and with the circumstances under which the nest has been built. Sometimes the case is so thin that the comb shows an edge through the wall, while sometimes it is composed of as many as a dozen layers. But, however the thickness of the walls may vary, as a rule so invariable as to have been adopted as a means of classification, the combs of the nests of the *Vespæ* have no connection with the outer case, except at the top of the nest. The comb and the case are mutually independent and separate from each other.

The combs, unlike those of the honey-bee, are laid horizontally, stage below stage, each hanging from the one immediately above it, without any reference to the rest of the series. The two or three uppermost stages of comb, into which the first rudimentary cells have been expanded, are, in course of time, worked into the case of the nest at their edges. And the cells are cut down to allow room for the wasps to camp on the upper surface of the comb beneath. Wasps do not stand cold and wet, so a shelter is here provided for them, where they may be kept dry and warm, without interfering with the comfort and safety of the larvæ in the lower stages. Incidentally another advantage is gained by this

arrangement. For the fabric of the nest is thus materially strengthened, by substituting, at this vital point, a hard, dry, light flooring for the loose, damp comb, which is almost ready to fall to pieces by its own weight.

When a new stage is to be constructed, the wasps begin by raising the walls of two or three adjoining cells in the centre of the lowest comb. From these diverging roots a round cord is drawn out, as it were, on the end of which little cells are made, just as on the end of the footstalk from which the nest originally sprung. As each cell takes shape an egg is deposited in it, so as to lose no time; and while its walls are gradually rising, the comb is gradually spreading, by concentric rings of cells. The mother wasp follows close on the traces of the worker, and the circles of larvæ of the same age shew the system on which the comb has been made. As the comb spreads, new stays are let down to support the weight increasing with the width. Meanwhile the expansion of the case keeps exact pace with the lateral growth of the comb; the old case is nibbled away within, and new paper is laid on outside, so as to make room all round the edge. And, before each stage has attained its full dimensions, another has been commenced below it, just in the same manner.

There is something in all this very different to the economy of a bee-hive. There all the building instinct is concentrated in one point, and the only variety which the work offers, beyond the distinction of large and small cells, is the occasional appearance of a queen cell, disfiguring the symmetry of the

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comb, and a sign of coming political disturbance. But in a wasp's nest the most varied building operations are going on simultaneously. The case has to be made, and the foundations—reversing the application of this term—constantly attended to. And as all has to be done in a few weeks, and time is very valuable, what presses most must be done first; and so the cells are merely sketched out in the first instance, but not built up till opportunity allows. And the social life of the insects corresponds. The bee-hive has its type, political excitement and all, in a flourishing manufacturing town; the wasps' nest finds its parallel on the outskirts of civilization, in the ready and versatile industry of those who live with their lives in their hands.

In many respects wasps are more easily watched in their proceedings than bees. With a little care and patience we may trace the exact process by which the outer case of a wasp's nest is built. But the internal economy is most jealously shut out from observation; we cannot study this as accurately as in a beehive. We may watch marked wasps come in and go out again, but we cannot tell what is going on inside all the while. For the first effort of the swarm is to surround all their work, and exclude all curious eyes, by a thick covering of paper. I have never seen, after watching two active swarms for a long time, the actual process of building a cell; but Mr. Newport* was more fortunate in the observation of his hornets, and describes the process as identical with that by which the outer case is made. The materials are laid on at the edge of the cell-wall,

* Op. cit. 'Trans. Entom. Soc.,' Vol. III, p. 189.

in the same way; but they are rather finer, and the work is more regular, than in the case of the nest. But though we cannot see all their proceedings just when we wish, the results are easily intelligible. By the indications of the variegated colours of the materials, and by the line of fracture when we tear up the softened cells, the details of their construction can be readily made out. The microscope tells us that the comb is made of the same materials as the case, but the paper is perhaps rather thicker, and of a closer texture. In the first beginning of the nest we saw how the four original cells took the form of so many little pockets attached to the footstalk; and this is still just the form which they take at the edge of the growing comb;—little pouches, with three straight sides where they fit on the cells already built, and one longer curved wall on the outer face. As the cell-wall rises, and the little pouch takes its place in the ranks as a cell, its transverse section displays a regular rectilinear hexagon; and the surface of a finished wasps' comb presents a series of as beautifully symmetrical hexagons as the comb of the honey-bee. But, for this result, it is necessary that the work should go on regularly. In the combs of a second nest, where the work has been carried on hurriedly, and under the guidance of many mistresses, the form of the cells is very irregular, round or square cells, irregular hexagons, and occasional intercellular spaces being often met with. And, generally speaking, the outermost cells of all combs, by whatever species they may be made, are not constructed with the same geometrical precision as the central cells. The free wall is either a seg-

ment of a small circle or, if angular, the angles are rounded off and irregular. Judging at least from the specimens in my cabinet, including nests of several varieties of *Polistes*, *Raphigaster*, and *Icaria*.

The regular form of the cells of the honey-bee has long attracted attention, and the fact has been settled, beyond all question, that they are built with the strictest mathematical accuracy, as equilateral and equiangular hexagonal tubes. The cells of the wasp are of as regular construction as those of the honey-bee at the sides; but at the bottom, which is the part of the honey-comb that has more particularly engaged the attention of mathematicians, there is no evidence of any geometrical instinct.

The nature of the influence under which the cells are constructed with such wonderful accuracy is a problem of the highest interest. It has generally been discussed with particular reference to the cells of the honey-bee. But wasps' cells are on some accounts to be preferred for the examination of this question. The nature of the materials of which they are made excludes the hypothesis that the cells owe their hexagonal form in any degree to the crystalline cleavage of the wax. And the evident mode of construction of the paper cell shows that the wax cell need not have been built solid and hollowed out subsequently to prove so exactly regular, but may have been—as indeed it is—raised at once in its accurate outlines.

There are two theories on this subject. One theory refers the hexagonal form of the cells to objective influences, to a physical necessity, comparing the formal results of the conjoined labours of many

insects to those of an uniform lateral pressure, under which cylinders of any soft substance take an hexagonal form. This comparison, however, is fanciful, and is not quite supported by facts. For some wasps make their combs—very small ones it is true—entirely of cylindrical cells, the lateral pressure notwithstanding. The other theory refers the form of the cells to a subjective influence, an instinctive impulse; and to this I must express my adhesion. It is not a fatal objection to this theory that wasps, where they are free to build in any form, as, for instance, at the edges of the comb, build cells of less regular shapes; for the hexagonal principle may still be traced in these irregular cells, though the result be obscured somewhat by the stronger impulse, if I may be allowed to say so, of not taking unnecessary trouble where nothing is to be gained by such scrupulous accuracy. So far, indeed, from these irregularly hexagonal cells disproving the instinct theory, their occurrence is rather an argument for its correctness. For we cannot explain why such cells should take an hexagonal form at all, however rudely expressed, except on the assumption that they are built under an instinctive impulse.*

Each building pellet is applied with great exactness to three sides, two of one cell, and one of an adjoining cell. In this way the cell-walls are interlaced with one another; and much greater strength is given to the whole comb than if the three outer sides of each cell were built up independently of the three

* This subject is discussed by Mr. Wood, and illustrated in his usual happy manner, both as regards bees and wasps, in 'Homes without Hands,' pp. 432 and 570.

inner walls, or of the adjoining cells. Still, as the comb grows by constant additions to the outer edge, its weakest point, its line of fracture, runs in concentric circles. And any attempt to wash an old comb is likely, without the greatest care, to induce a tear in this direction. The sides are built up, streak by streak, as the cells expand from narrow pouches into large regular hexagons formed with geometrical precision. To allow for this gradual expansion, the comb takes a curved form, presenting the convexity downwards. The central cells are vertical; a little farther off from the centre they only maintain this direction by having the first narrow portion turned round, like a little horn. Still farther out this expedient is insufficient to meet the increasing divergence, and at last, in some species, the cells are placed almost horizontally.

With this exception of the direction of the outer cells, all the species alike make their comb on the same pattern, or as nearly so as the capabilities of the material employed will allow. The brittle wood chips which *V. Crabro* and *V. vulgaris* generally employ do not allow of the same lightness of construction as the tough fibres which other species prefer. So their combs are thick, and the cells stand parallel, quite up to the edge; and the structure has none of the convexity which gives such a light, graceful appearance to the large combs of the tree-wasps.

The upper surface of the comb has little to attract our attention. It is of a dull dirty aspect, studded over with little round points, each of these eminences corresponding to the bottom of a cell. The open space between this and the under surface of the stage

above is interrupted by suspending rods, or pillars, connecting the two combs. These are placed at irregular intervals, but in a regularly graduated size; the mainstay being in the centre, and the slighter supports nearer the edge. The lower ends of these pillars are attached artistically enough, the base spreading like the bole of a tree, with stays running out here and there. But the upper end looks very ragged and untidy, being, as we have already seen, nothing more than the prolongation of the adjoining edges of two or three cells, which only gradually take the form of round pillars.

Wasp-paper, the substance of which these delicate structures are all made, is composed of various substances which are clearly distinguishable under the microscope. Each species of wasp has a choice of materials, some preferring wood fragments, some herbaceous filaments, but nothing seems to come amiss when the ordinary supply fails. And grains of sand, fragments of bark, paper cuttings, or any other waste, are often found among the more usual ingredients of wasp-paper. The hornet prefers fragments of rotten wood, with which we often find much sand intermixed. *V. vulgaris* makes use of the same materials as the hornet, but the particles are smaller, and better adapted to her own capacities. Sometimes, however, she will make use of herbaceous filaments, and the style of her architecture, like that indeed of all other species, differs according to the circumstances in which she is placed.

Thus, to take this instance, in the summer of 1864, I had the remains of two nests, of *V. vulgaris*, which

had been thrown together into a fern case for the benefit of the chickens, sent to me. One nest was of a dark brown colour, composed chiefly of herbaceous filaments. The other was of the more familiar fawn colour, and composed of fragments of rotten wood. When the wasps recovered from their stupefaction, and recognized the altered circumstances to each other and the outer world under which they were placed, wasp-like, they set to work; and the two swarms, having amalgamated, proceeded to make one establishment out of the ruins of the two old ones. For two months they continued to work, shut up in the fern case, in a most pestiferous atmosphere, and fed only on brown sugar. When the mass or mess was sent me, the yellow nest seemed to have been deserted. The comb of this was all nibbled away, and the materials had been used to patch and extend the brown nest withal. The new paper was somewhat glutinous, and smoother than ordinary wasp-paper, probably in connection with the unnatural state in which the wasps had lived. And it was not laid down on the usual plan of the species, in prettily varied shelly patches, but in one large sticky-looking sheet, streaked with undulating lines, and coloured irregularly from the indiscriminate use of the light or dark material.

But, however the substance may differ, it is made up, or manipulated, if I may transfer this expression, by all the species alike in the same way. To a certain extent the cohesion of the particles is mechanical; for a kind of felting or interlacing of the fibres may be traced in the paper of some nests. But the materials are for the most part held together by the

mucous secretion with which they are worked up into a pulp. This mucus, gum, silk, or whatever we call it, is, as we have seen, the representative of, if not actually identical with, the secretion with which the larvæ form their cocoons. In many insects it is suppressed, in others materially altered, when the pupal stage is past: for with the formation of the cocoon the necessity for such a secretion commonly ceases. In wasps however, with the necessity, it continues but little altered for at least a portion of their imago life. It resists the action of cold water, otherwise every passing shower would injure the coverings of the nest. But boiling water or alkaline solutions readily dissolve it, and reduce the paper to a pulp. This can be re-made into a texture not much unlike the coarse paper in which sugar is wrapped, only more brittle; or into a *papier-mâché*, still more inferior to any marketable article. Wasp-paper supplies one of the very few instances where the natural is far inferior to the artificial product. It could hardly be otherwise, made as it is of an inferior staple, and by less efficient mechanism. But the paper which would not answer our purposes is perfect for all the wasp's requirements; it is just like everything else in the insect economy, just what they want and no more. For Britain, with its sun and showers, this slight paper case is quite enough to keep out moderate wet and cold, and to let in the air. In the East Indies, where a long dry season, uninterrupted by showers, lasting a wasp's life-time, may be looked for, a ruder material is often employed: and the great *V. cincta* builds her nest of mud. Not to draw too wide an inference from limited opportunities of observation, still I would

add that, again, in Demerara, where no such long dry periods are to be reckoned on, and where rain falls at any time with a violence which would dash our British nests to pieces, a substance is used adapted to the exigencies of the situation. And so the little *Chartergus* makes her house of a card-board which would indeed call forth a manufacturer's admiration. The material employed is the finest cotton down, and as many as sixteen or more layers of this may be counted in the hard card-board walls of the nest. Washing one of our English nests is an operation not to be lightly undertaken, but the nest of *Chartergus* will bear, and, from what I have seen, generally requires, a pretty free use of soap and water. But I write this under the possible correction of a larger experience. For the nests which I have seen represent but a small portion of what are found in these different quarters of the world.

This much British wasps' nests have in common : the story is very nearly the same, whichever species may have been particularly under notice. Whether hanging from a spray exposed to the wind and rain, or buried under ground, whether lodged in the rotten trunk of an old hollow tree, or more comfortably attached to a roof-beam, the nests all begin and go on in the same way, and, if they survive the various accidents to which they are liable, come to the same end. The various species, however, all adapt their structures, to a certain extent, to the circumstances under which they are placed. The hornet makes a less elaborate case round her comb when the hollow tree which she has chosen renders

such a protection unnecessary. The dense rugged texture with which *V. germanica* keeps off the drip and the falling earth from her nursery when she builds under ground, is changed for a lighter, freer style of construction when she hangs her nest from a rafter. And so it is, too, with *V. vulgaris*.

The assurance of a coming dry summer is communicated to wasps by signs which we take at second hand from them. I am told, by a gamekeeper who has spent his life in a land of brooks, that the height at which the wasps make their nests above the water is a rough index of the amount of rain that is to be expected during the summer. In a wet season they choose the top of the bank ; in a dry year they extend their range nearer to the water-level. When these indications, whatever they may be, induce *V. sylvestris* to build in the hole which she has scooped in the side of a hedge-bank instead of in her more usual position, she makes a much slighter case than when she has to provide against wind and rain. But the structure is still characteristically that of the species in all these cases ; and the nest, in whatever situation it may be placed, and however it may be modified to suit the requirements of its unusual position, bears distinctive marks of the workmanship of the particular kind of wasp. The architecture is as typical of the species as the markings of the insect, and the instinctive habit of building in one particular way is as inseparable from the individual as its own organs. Though an occasional alteration of the seasons may give rise to corresponding changes in the place or mode of construction, yet these changes, do not go so far as essentially to

alter the style of the nest. A permanent alteration of the climate, such as the insects could not adequately temper for themselves, would probably destroy the local species, and cause the naturalization of others from foreign countries. But though a change of seasons and climate might bring the *Chartergus*, for instance, here with her card-board nest, there is no reason to think that any such climatic changes would induce the British wasps to build card houses.

One thing more British wasps' nests have in common, namely, the end of all their labour, the wreck and ruin of their wonderful fabric. Where no accident has interfered with its growth, or brought it to an untimely end, the limits to the size of a nest are prescribed by physical and physiological laws. The latter class, to which we shall return farther on, are probably the most important, but certain physical considerations lead to the conclusion that a paper structure of this nature cannot grow very large. In the species which use a more textile material, the constantly increasing deviation of the marginal cells from the normal vertical direction has probably something to do with limiting the lateral growth of the comb. And where the more friable nature of the materials excludes this particular limitation, compelling the cells to be built straight and parallel throughout, in this very circumstance we have another not less important influence at work, restricting to a few inches the diameter of a comb which could have any reasonable chance of holding together. And so, too, with regard to the number

of tiers of comb; the nature of the material prescribes very narrow limits within which the number of heavy wet combs, hanging from one another, can be safely multiplied; even were there wasps enough to extend the fabric, or did the season allow them to prolong their operations, indefinitely.

Then, as to the duration. The history of even the most long-lived swarm of wasps extends only over a few weeks. The end comes very speedily as well as surely, whatever the cause; and the story of the decay of the nest, whose growth we have traced, may be told in a few lines. Thus:—No additions are made to the structure, the repairs are neglected, the loose ends are not neatly cut off and fastened down. A few idle wasps hang about; but the nest seems almost deserted. Perhaps a shake of the hedge will bring out a few fussy wasps for a minute, or a sunny afternoon will develop signs of life in the remains of the swarm, yet their strength is gone. A cold night or two, a few damp cold days, and all is over. Now, the collector may take his prize safely; and he must be quick about it, for, if he delays, the rain and wind will soon destroy whatever of this curious structure the moths, and wood-lice, and earwigs have spared. These, and other insects abhorred of all naturalists who have collections, are now its occupants.

*Lucifugis congesta cubilia blattis.**

The little creatures who made it and held it against all comers have succumbed to cold, and disease, and old age, like other brave soldiers. They have skulked

* Virg. 'Georg.' IV, 244.

off to die, like old cats, away from home; and the most unlikely place to find a live wasp in is an old wasps' nest.

We have now, to complete this part of the subject, to inquire how the nests of the several species differ respectively from the common type, and what are the marks by which we can identify them. In the earliest stage of its existence the nest, as a rule, displays nothing very characteristic of the particular species. After the examination of some dozens of the embryo nests of the common British wasps, I must confess that I should have great difficulty in referring each of these to its proper owner. As they grow larger the difficulty vanishes, the form of the nest, the details of its structure and the materials of which it is composed, all, as we shall see, coming to our assistance in drawing the distinction.

The hornet (Plates VI. and VII.) forms her nest of a brittle, yellow, thick paper, composed of fragments of rotten wood, often mixed with sand, or with any thing that can be glued up into a mass. Hornets' nests are not generally as populous as wasps' nests, and the swarm is more economical of its labour. They do not always care to cover the comb with a distinct case of paper when the cavity in which the nest is built might seem to render any additional protection unnecessary. However, when the nest is built in an open space, as in a roof, the case is quite as thick in proportion to the size of the nest as any of the smaller wasps would have made it.

The outer cases of wasps' nests are made on one of two general plans, which may be called the cellular or laminar respectively. Hornets' nests, like those of *V. vulgaris* and *V. germanica*, are made on the former plan. A transverse section shows the entire thickness to be built up of segments of circles applied irregularly one over the other, something in the way that semicircular tiles are built into ornamental walls for suburban villa gardens. Hunter,* says:—"A section of the outer coat from top to bottom would almost give the idea of its being built with the wafers made by the confectioners." By this mode of construction a number of tunnels or, more correctly, long *culs de sac* are made, generally running parallel to the vertical axis of the nest. The outside of the nest is uneven with the openings of these tunnels, which are all directed downwards; but the inside is smooth, with a clear way all round between the case and the combs. The nest is most commonly of an oval form, with the long axis vertical.

Everything, of course, is on a very large scale, as compared with the nests of the smaller species. Taking the measures from a large specimen in my cabinet, which had been built in a cottage roof in Gloucestershire, these quite eclipse the proportions of the ordinary wasps' nests. The transverse diameter is fifteen inches, and the vertical measure is as much as nineteen, although full three inches or more have been taken off the bottom of the nest. The span of some of the longitudinal cells or tunnels is six inches, and their average width is not less than

* Hunter 'Posthumous Works,' by Owen, Vol. I, p. 74.

two or three inches. But this is altogether a very large nest, larger than any I have seen elsewhere.

The embryo hornets' nest is somewhat different from that of the other species, it is shorter and clumsier, and my specimen, taken from the roof of a stable, wants an outer cap.

The nest of *V. vulgaris* (Plate VIII.) is very similar to the hornets' nest, both in the nature of the materials employed and the mode of its construction. But there is no difficulty in distinguishing the miniature from the coarse work of the larger insect. The fragments of wood are smaller, and the colour much more varied; and the whole structure affects rather a globular than an oval form. The cells of which the outer case is made are small, short, and irregular, quite unlike the long tunnels which the hornet builds. Their vaulting is made of shelly patches, the lines in which are disposed in concentric curves of a short radius, with the concavity mostly directed downwards, arching across the open ends of the vaults. These nests are friable to the last degree, and cannot bear any handling. There is nothing in wasp architecture more beautifully symmetrical than a large comb of *V. vulgaris*, nor more prettily varied than the case of the nest. And I am sorry to add that there is nothing of this kind more perishable.

The hornet prefers to build in a roof, or in the hollow of a rotten tree or post, above- or, sometimes, under-ground; *V. vulgaris* has a more varied taste, for, though she is an underground wasp by preference, yet she will build in roofs, and in the most out-of-the-way places, among which a dovecote, a

pump, and a sugar-loaf, are included. Professor Edgeworth,* who has made this species his particular study, finds that ninety per cent. of its nests are built in close proximity to those of the *Bombus terrestris* or *agrestis*. The neighbours are said to live on excellent terms. For whose benefit is the relation maintained? Does the wasp court the society of the bee, or the bee seek in the neighbourhood of the wasps, protection from her enemy the field-mouse?† A somewhat similar relation is said to exist between the mocking birds and the pasteboard wasps; the birds building over the wasps' nests to secure their young from the attacks of the monkeys.

V. germanica (Plate IX.) makes her nest either in the ground or hanging from a rafter. Underground, of course she adapts her work to the necessities which projecting roots or stones involve; but, when she is at liberty to build in any direction the nest takes the form of a sphere flattened at the poles. The materials employed are vegetable fibres, which are felted together into a dull grey texture, wanting all the elegance of colour and arrangement of the nest of *V. vulgaris*. The same shelly patches indeed are to be seen, but in the mode of their arrangement they bear no constant relation to the whole work. They seem to be laid on anyhow, merely to cover space; and instead of springing in arches they lie nearly flat. Many of the patches are complete circles. These are all made from without inwards, in concen-

* Notes on Irish Vespidae, 'Annals and Magazine of Natural History,' Vol. XIII, p. 466. June, 1864.

† Darwin 'On the Origin of Species.' p. 74.

tric lines, and a little hole in the middle marks the spot through which the last artificer withdrew her mandible when she put the finishing touch to her work.

I am writing with a singularly clean and beautiful specimen of the work of this wasp before me, which was taken from a cottage rafter at Warbleton. But this is quite an exceptional specimen, for the cases of all the other nests of *V. germanica* which I have seen dug out of the ground are most uninviting: they are rugged, dirty, without any attempt at arrangement of the work; and the dull grey hue of the paper, instead of being relieved by white lines, is generally made still deeper and duller by earthy soils and stains. The combs are not made so rigidly straight as those of *V. vulgaris*, but they are not curved as gracefully as those of the tree-wasps.

V. rufa (Plate X.), though a ground-wasp, builds her nest on the laminar, not on the cellular plan. But the structure has characters of its own, by which it may readily be distinguished from the tree nests which are built in this way. The successive layers are not perfectly free from each other, but tacked down here and there at the edges. And these edges are very numerous, marking the whole surface with frequent ridges, like the lines of sheep-tracks on a Down hill-side seen from a distance. I have only one specimen of this kind of nest, for which I am indebted to the kindness of Mr. F. Smith. This is in the form of a flattened sphere, pressed in equally at the top and bottom, though not quite to such an extent as the nest of *V. germanica*. The entrance is lateral,

single, oval, the edges very neatly finished off and not prolonged into a horn. The material is vegetable fibre.

The marginal cells of the comb diverge from the vertical direction to a slight extent, but the comb looks stiff and heavy, and this nest does not give an impression of any great constructive ability. The general plan is less bold, and the texture less close and firm than the work of the other species which build on the same plan. Beyond the fact that *V. rufa* is a ground-wasp, I cannot say where its nests are likely to be found. The barrenness of my cabinet is indeed a proof that I have never looked in the right place for it. It is said to be very common at Bournemouth. In Ireland it is rare. It is an early wasp, for while the other species are still in full activity, this wasp has done its work for the year and abandoned its nest.*

The nests of the tree-wasps, like those of the ground-wasps, have each their own distinctive character. For beauty of appearance none of them can be compared to the nest of *V. vulgaris*; but in their elegance of form and perfect adaptation to their purposes they are quite unequalled.

The queen of paper-makers is *V. britannica* (Plates V?, XI. XIII. XIV.). Her nest is distinguished from those which we have already noticed by the fact of the paper being made in large sheets, with long, nearly parallel, stripes running horizontally round the nest. It resembles in this respect the nest of

* 'Edgeworth,' op. sup. cit. p. 472.

V. sylvestris, which also presents broad, smooth sheets. But the nest of *V. britannica* is of a thicker structure and more compact: the sheets are more numerous, closely overlying one another, and the edges are pressed down on, and often attached to, the sheet beneath them. From the specimens which I have seen, I am inclined to believe that the strong contrast of colour of the different stripes, indicating a very varied source of supply of materials, is highly characteristic of the work of this species. They are most determined builders; the remains of a swarm will immediately set about to replace the nest of which they have been robbed; and the neighbouring twigs, under these circumstances, garnished with scraps of paper, attest the misdirected energies which could not be repressed till the new nest was far enough advanced for all the wasps to find space to work at, or an end to join on to.

This species generally builds in low bushes or hedgerows, though I have one specimen from the top of an apple tree. The outline of the nest is pear-shaped, that is to say somewhat drawn out at the lower part where the entrance is situated. This is single as usual, and lateral, and instead of a simple hole there is often a little horn here, a kind of porch in which the sentinel, whom it is the habit of this species of wasp to post, mounts guard. Dissimilar as the mature nest is to that of *V. germanica*, yet in the embryo state the nests of the two species cannot be distinguished from each other. It is made of vegetable fibres.

The tree-wasps are less common and have not so

wide a range as the ground-wasps; and this species in particular is confined to certain localities. In the hot summer of 1864, when wasps were everywhere, *V. britannica* built freely in the neighbourhood of Brighton, to the astonishment of the natives of these parts. But generally, the only tree builder about here is *V. sylvestris*. In the part of Gloucestershire from which my supplies of wasps and wasps' nests have chiefly been drawn, this is the most common species of tree-wasp, and on it my observations on wasps in general have been chiefly made.

V. sylvestris (Plates VI. XII.) makes a nest which, from a very early period of its existence, has a distinct character. It is not a little bunch of cells at the end of a footstalk, standing in a cup open at the bottom, but the cells and the first envelope are surrounded and shut out from view by a little ball or bell of the most elegant and delicate form.* At the bottom is a round hole, with the edges slightly turned out. Over this are laid one or more separate hoods of the same slight graceful construction, but not reaching so far down as the mouth of the bell in which the second coat terminates. The striking resemblance of this pretty little nest to a toy-bell has added to the many other names of the species that of *V. campanaria*.†

* *V. saxonica*, the common tree-wasp at Lausanne, makes its embryo nest in the same elegant pattern. I do not know whether this was the wasp which inflicted the stings which Fabricius Hildanus records, but it has great vitality. A little box of nests which came in a friend's trunk, by a very leisurely journey, supplied me with plenty of live specimens.

† This nest is figured in Mr. Knapp's well-known 'Journal of a

Though the little bell disappears in the further development of the nest, yet the complete structure of *V. sylvestris* retains many of the characters which marked its early stage. We may always notice the broad, even sheets, with their free edges hanging in flounces; and the general lightness and slightness of the covering contrasts with that of the thick, strong nest of *V. britannica*. Like that, but in a less degree, this species makes its nest pyriform; and it uses the same materials, namely vegetable fibres. The aperture is central. The comb is less hollowed out on the upper surface, and there is less divergence of the lateral cells than we find in *V. britannica*. Both in the original construction and in subsequent restoration of the nest *V. sylvestris* is less profusely extravagant of paper than the species last described.

This is, according to her markings and her general habits, a tree-wasp. But no place comes amiss; hollow trees, caves, hedge-banks, and bee-hives are all in their turn honoured by her selection. I think that Gloucestershire is not as congenial to her as the drier parts of England.

V. arborea is not represented in my cabinet, nor in the splendid collection in the British Museum; and I have been unable to obtain a specimen to engrave from any source. Though a ridge about four miles distant from Wakefield, in Yorkshire, and to the

Naturalist,' 3rd ed. p. 382, and Plate VI, fig. 1, its successive stages being very well represented. But the description was written before the Natural History of Wasps had been made clear by Mr. F. Smith, and *V. campanaria* is set down, p. 382, as a solitary wasp.

North, has been urgently pointed out to any one wishing to obtain a reward for procuring me a nest of this species. The nest is said by its original discoverer to be not unlike that of *V. britannica*, and to be found in fir-trees. My females were taken in Gloucestershire.

CHAPTER VIII.

SOCIAL ECONOMY OF WASPS.

HISTORY OF THE COLONY. LARVAL PERIOD. LARVÆ OF THE HONEY-BEE. DEVELOPMENT OF THE BROOD. THEIR SOCIAL LIFE. HABITS OF WASPS. THEIR DISEASES.

IN the last chapter we traced the history of a wasps' nest from its first beginning to its decay and ultimate destruction, and noticed the chief characters by which the work of the different species may be distinguished. We must now, to some extent, go over the same ground again, tracing the history of the living occupants of these nests during the few weeks to which their existence is limited. Much of this information is to be obtained by watching the wasps at work, and by examining the combs after the nests have been taken. But there are other points only to be ascertained by experiments, such as Nature herself may make for us, or which our own studies may suggest. It will be most convenient to keep these branches of the subject separate, that the particular experimental inquiry may supplement the more general survey of the social economy of the swarm.

The mother-wasp, as we have seen, on awaking from her winter's sleep sets about the construction

of her nest. As fast as each cell takes shape she deposits an egg in it, generally on the inner side of the pouch, and in a corner, firmly glued to the wall. When the cell has been used before it is of course lined with the cocoon of the previous inmate. This makes no difference in the adhesion of the egg, as the glutinous secretion in which it is enveloped penetrates the lining, and fastens the egg through it to the paper wall. But the height of the wall makes a difference as to the position of the egg in the cell, for, as the mother-wasp can only reach to a certain distance with her abdomen, the egg is fixed nearer the mouth of the cell when this is an old one, than when she follows close on the traces of the workers, and deposits the egg before the cell-walls have been built up to their full height.

The egg stands out obliquely from the side of the cell, as a little white speck about half a line long, and in this position it hatches. The larva, however, is not immediately set free from confinement on hatching, for the tail remains fast within the egg-shell. On this centre the larva moves freely; it feeds and grows, but cannot get away from the spot on which the egg was laid. The vertical direction of the cells makes this provision necessary, for a moment's consideration will show that, without it, as soon as the larvæ were hatched they would fall out of their cells and die. The embryo wasp has, even at this early period of its existence, a pair of mandibles, distinguished from the pair which it next acquires by the greater length of the central tooth, and mounted on a horny frame very like the bows of a pair of spectacles. These deciduous mandibles are

meant for real work, and are not merely the rudiments of something which is to be developed into a useful organ in the perfect insect. When they have served their turn they are cast off, with the first skin, and may be recognized lying at the bottom of the cell, or hanging on its walls with the discarded egg-shell.

But we have not discarded the egg-shell yet. For the larva, after its first moulting, still, for a while, remains anchored by the tail to the place of its birth, fixed in its egg-shell. Though the tether becomes hourly longer, and the larva has more extended movement in every direction. As the larva grows it has to seek, further back in the cell, a position adapted to its future requirements. This change of position would seem to be a very perilous operation, judging from the large number of small larvæ which are cast out of the nest. For, if the embryo loses its hold it falls out of the cell, and the workers, acting on the maxim that everything out of its place is dirt, immediately remove the helpless grub from the nest. They do not kill or eat the grubs, at least, not in the first instance, they merely carry them away, as they would any other useless material. Hunter* has seen the wasps replace in empty cells grubs which had fallen out of the nest. But this is not their usual practice. Something of the same kind has been observed on a larger scale, where larvæ of one nest were transferred to another at some yards distance.† But it is doubtful whether

* 'Posthumous Works,' Vol. I, p. 85.

† Smith's 'Catalogue of British Aculeate Hymenoptera,' 1858, p. 214.

the larvæ were not taken to the larder rather than the nursery.

How the change of position is effected I cannot say from actual observation, but, as all the means which are at the embryo's command are sufficiently obvious, it is easy to see how only it can be done. The larva can lengthen or contract, stiffen or relax its body and bend it in any direction, and it has an instrument by which it can attach either extremity of the body at will to any neighbouring object. Obviously, by these means it can travel up and down in its cell, provided only that each one of the prehensile organs be strong enough to sustain the whole weight while the other is being shifted. And the operation will be more rapid and safe, just in proportion as the size of the larva gives it a longer step or reach.

The mandibles are the prehensile organ at one end of the body; at the other end this is supplied by the peculiar conformation of what we must call the legs, though to most people the tail might seem the more appropriate denomination. A perfect insect has six legs; and, in larvæ which have a greater number of legs, such as the caterpillar, the temporary or larval legs are quite distinct from the six rudimentary legs which are to support the insect through life in a more highly developed form. The true legs of the caterpillar are but claws in their embryonic form; and the larval legs are merely oval suckers, each surrounded by a ring of bristles. The larva of the wasp has but one pair of larval legs, which are connected with the last segment of the abdomen. And, as the requirements of the wasp-embryo demand, these take a form quite unlike that

of the larval legs of the caterpillar. Indeed, the name of legs may seem to be scarcely at all applicable to them. Thus, within the circle, and below the level of the last abdominal ring, a tubercle rises, nearly in the centre of the depression. This tubercle is divided at its base, and so gives origin, on either side, to a fold of the integument, which sweeps round, concentric with the outline of the last abdominal ring, so as to almost to meet its fellow on the opposite side. These two half rings can be protruded or withdrawn at the will of the larva. When they are withdrawn a vacuum is formed within the abdominal ring which is applied to any surface, and the sucker holds. When they are protruded the sucker is set free. A firm outer ring, with a softer central piston capable of voluntary protrusion and retraction, is the instrument generally employed for frequent temporary adhesion throughout the animal kingdom. We have seen this in the simplest form in the fly's foot. The organ now under examination is much more powerful and more complex. Though unequal to the support of the large heavy larvæ, on the rough surface of the cell-wall, for any length of time, it is quite sufficient to sustain the weight of the smaller grubs. By its means these will cling to any object, such as a pencil or a finger, and they may be held suspended thus for a half a minute or longer. It is quite perfect for the temporary purpose of maintaining a hold on the cell-wall during the alternate movements of the body, as it can be applied or disconnected in a moment; and during the elongation or retraction of the larva seems almost to act of itself.

The larger larvæ retain their hold on, and move up and down, in their cells by means of a peristaltic action;* by which also respiration is maintained. But for this it is necessary that the larva should quite fill the cell, or at least be in contact with two opposite walls. Now, the larvæ when they are about to change their position in the cell are much too small to hold themselves up in this manner. The only way in which they could touch two opposite sides of the cell at the same time would be by stretching themselves across it lengthwise. I cannot say whether the points of alternate attachment for the sucker and the mandibles, on this journey, are found on the same or on opposite sides of the cell, whether the larva climbs like a caterpillar, or something like a chimney-sweep. For I never observed them travelling, but I have often found them preparing for the journey, the larva having turned on its pivot, so that its head was directed to the bottom of the cell.

And now, this perilous journey safely accomplished, the larva feeds more greedily and grows larger day by day, in preparation for its transformation into a pupa. This preparation dates from the moment that it has reached the bottom of the cell. Arrived here it at once begins to weave the silk lining which is to protect it from external influences during the pupal stage. Were the formation of this web delayed to a later period, the size of the larva would

* Mr. Newport, 'Trans. Entom. Soc.' Vol. III, p. 189, sup. cit. says, from personal observation, that the hornets maintain themselves in their cells by a vermicular movement. When the larva has travelled thus to the mouth of the cell, it makes a sudden longitudinal contraction of its whole body, and thus regains its position at the base of the cell.

prevent it turning its head in its cell so as to reach the bottom, and the covering would only extend half-way down. And the insect would come out crippled, because the juices of the pupa had evaporated too rapidly. However, in the regular course of things, the larva eats and grows, and while it grows it spins the lining to its cell. At first it seems to do nothing but eat, but at last it gives up eating altogether, and only spins. The head is no longer put out asking for food, but moves about just like that of a caterpillar spinning its cocoon. And, as we watch, a round white cap rises high over the paper margin of the cell; the larva retires from sight; and the nurse-wasps transfer their attentions to other little heads which peep forth from the outer rings of the comb.

The larva now casts its skin a second time. In the first moulting only the skin was shed, but in the second, not the skin only, but such parts of the larval body as the perfect insect will not require are cast off. Among these are the second pair of deciduous mandibles. Who can enter far enough into the secrets of a wasp's infancy to say what is the use of the long central tooth in its first pair? Surely, if the larva had set out on its travels thus equipped, one would have found a use for this pointed tooth in hanging on to the cell-wall. But the second pair have the three teeth all of nearly



Fig. 12.—Successive forms of the Mandibles.

1. Of the larva in its first skin.
2. Of the larva in its second skin.
3. Of the perfect insect.

The relative proportions have been carefully preserved.

equal length. Besides these, we find the lower end of the bowel, containing all the undigested food and excretions which have accumulated there since the larva first began to feed. The reason of this singular arrangement will be obvious on a little consideration. Placed as the larva is, vertically, in a closely fitting cell, which it cannot leave, and from which there could be no drainage except by the side of its body, it is necessary to provide against this contingency, and also against the decomposition of the excreted matters. The object is effected, as usual, in the simplest possible way: the excreta are retained not only within a membrane, but within the body of the larva, secured, as far as may be, from chemical influences, and from becoming a source of injury to the helpless larva. Thus:—in the larva of the wasp the bowel does not open by a vent externally, but terminates in a blind pouch, which receives all the excretions and the undigested residue of the food. The smallest atom of a larva has often a dark speck visible through its skin. This grows larger, with the growth of the larva, till the second moulting, when it is cast off with the skin, as a hard black mass closely invested with the membrane which formed the end of the bowel. On examination with the microscope, this mass is found to consist of scales, hairs, and other fragments of insects, hairs of vegetables, and other substances less easy of recognition. From this inventory it would seem that, from the earliest period of their existence, these little mites are fed on chopped insects. An observation of Wildman confirms this inference, and shows that the mandibles of the larvæ are meant for real work, to

chop their food smaller still. For he has seen the adult wasps supplying the larvæ with masses of solid food of such a size as to require to be cut up into smaller pieces before they could be swallowed.* If the benefit of insects to man is to be measured by the number of other insects that they destroy, wasps must be our benefactors indeed.

When the perfect insect leaves its cell it leaves its prison history written on the walls in very plain characters. Here is the egg-shell, wanting only a little patience to spread it out in its full proportions. Here, close by, is the first skin, at once distinguished by the great length of the central tooth of the mandibles. Pressed down upon these relics of an earlier age, earlier by a fortnight perhaps, is the spiral coil of undigested food wrapped in its own membranes, a daily record of all that the little grub has eaten, or rather has failed to digest. On this lies the second skin and its mandibles, needing a great deal of patience to disentangle it perfectly; and on this, again, we may find as much of the cast skin of the pupa as has not been either swallowed by the insect just emerging into active life, or picked out of the deserted cell piecemeal by her elder sisters. And this story is repeated, in the same way, as many times as the cell has been occupied; egg-shell, first skin, excreted mass, second skin, and shreds of pupal investment lie in sets, in the same order as they have been cast off by each successive tenant.

There has long been a discrepancy of opinion

* Wildman, 'A Treatise on the Management of Bees,' &c. 4to. London, 1768, p. 153, "*so large that they were scarce able to swallow them.*"

among Naturalists as to the changes which the bee-larva undergoes, and the number of times that it casts its skin. The interest which attaches to the subject on this account, and the light which the history of the bee and wasp mutually throw on each other must be my excuse for a somewhat long digression into the history of the larva of the honey-bee. This inquiry is altogether much more difficult than the examination of the wasp-larva. For the structures are much slighter; they are not to be displayed without a great deal of trouble, and, after all, there is much less to see. With a saucer of warm water we can loosen and unravel all the parts of a wasp's comb, but the honey-comb requires long soaking in an alkaline solution to separate the silk lining from the waxen wall. Under this treatment, however, the cocoons will float out entire, and incidentally we may satisfy ourselves of a fact which has been often disputed, namely that cells which have not been used for breeding, but only for storing honey in, have no lining. Indeed, as the lining of the cell is the cocoon of the larva, it could not be otherwise.

As the bee-larva is fed on bee-bread, which leaves little or no indigestible residue, the grub is not provided with a large pouch within its body to receive such matters. The yellow substance which we find in the angles of the bottom of the bee-cell is shown by the microscope to consist almost entirely of pollen granules, and to be, in fact, identical with bee-bread. It is probably superabundant food which the larva has not eaten, and which has worked its way down to the bottom of the cell. It certainly is

not the undigested residue of food, for it lies outside the cocoon, and must therefore have been deposited there before the larva had begun to weave this, and had cast its second skin, before therefore the bowel of the larva has become pervious. Besides, the deposit lies loose, not enveloped in a membrane, as the contents of the intestines of the larva would have been. The absence of uric acid supplies another—however slight—argument in favour of the conclusion that this deposit never passed through the intestines. It is very small in quantity compared with the dark mass which encroaches so sensibly on the depth of the wasps' cell.

The thickest part of the cocoon of the wasp is at the cap, in connection probably with the fact that the faculty of making silk continues to be an attribute of the perfect wasp, while the bee only makes silk this once in her life. On the contrary, the bottom of the bee's cocoon is the thickest part of her flimsy structure. Held in shape by the adherent pollen granules, it seems to be thicker than it really is in this place. As the bee-larva grows its power of making silk gradually fails, and the cap of the cocoon is so thin that the workers have to make good the deficiency by plastering this end over with wax. Otherwise the pupa would be dried up within her case. It is curious to notice how one thing compensates for another; the wax cell-walls, and the elder sisters at hand to stop the pervious end of the cocoon with wax, make up for the slightness and deficiencies of the work of the larva.

The number of the successive tenants of a bee's-cell may be most easily counted at the bottom, where

the cocoons are thickest. Hunter* has reckoned as many as twenty separate linings, which, though they occupied little space when dry, swelled up when moistened with water so as to rise to the mouth of the cell. From the fact of the sac being quite closed at the bottom it is clear that the cocoon is commenced at a time when the small size of the larva allowed her to move about freely in the cell. But even then the lining could scarcely have been made so complete if the cell had not been placed horizontally, instead of vertically like the wasp's. A wasp-larva has to hold tightly to the wall of her cell all the time she is spinning, to prevent her falling out. But the connection of the bee-larva to the cell is altogether less firm than that of the wasp. Hunter† often found that the eggs and larvæ of his bees had been removed by the swarm from one cell to another.

The inventory of the bee's cell after the insect has flown seems at first sight very scanty, compared with that of the wasp. However, if we look close, we shall find everything there. Draw one cocoon very carefully away from another, and examine its rough end, outside, under water of course. On the yellow matter we shall find a whitish tuft, quite distinct in appearance from the cocoon membrane, which, from the fragments of tissues which it bears about it, is evidently a cast skin. Often a smaller and less composite membrane breaks away from this, which I believe, after careful examination, to be the egg-shell.

This is just the same as we have seen in the wasp,

* Hunter. 'Observations on Bees.' Works. Vol. IV. p. 466.

† Op. cit. p. 440.

the egg-shell and the first skin in close connection, and showing by their position outside the cocoon that this was not begun till after the first moulting. Within the cocoon we sometimes find fragments of the second skin, but the frequent absence of these fragments from the cell is explained by the fact that they are usually found adherent to the pupal envelope, which the bee carries out with her sticking to her legs and abdomen.

I feel no doubt, after having devoted a good deal of attention to this inquiry, that the above is a correct statement of the facts connected with the casting of the skin of the bee-larva; that the process is essentially the same in both the wasp and the honey-bee, and that in both alike the skin is cast twice, the cocoon being spun between the period of the first and second castings. Some writers* have denied that bees cast their skin at all. Swammerdam,† on the other hand, is often quoted as asserting that they do moult. His opinion, however, is not so very positively expressed on this point. The meaning of the few passages which relate to the moulting of the bee- and wasp-larva may be stated briefly. He infers, from analogy, that the bee-larva sheds its skin several times, but he cannot say how often; that the moulting is very complete, but much more difficult to trace by the exuviae in the bee than in the hornet; and that the remains of the cast skin are to be looked for adhering to the abdomen of the pupa.

* See 'Cyclopædia of Anatomy and Physiology. Insecta.' Vol. II, p. 876; also Burmeister, *op. cit.* p. 432, for references on this subject.

† Swammerdam. *Op. cit.* Vol. I. pp. 403, 417, 418, 542.

And now to return to the wasp-embryo, which we left, just entering on the sleep from which it was to awaken into perfect insect life, shut up in its silken covering. In due time the white cap begins to look a little dark, and a moist semi-transparent spot shows itself about the centre. Soon a mandible is seen to project through the membrane at this spot. By incessant snipping and scratching, the hole is enlarged sufficiently to allow of the escape of the prisoner, and out struggles a pale sodden-looking wasp. In a few hours the newly-born insect becomes undistinguishable from the rest of the swarm, except perhaps by her larger size. If we catch her, just as she has escaped from her prison, we shall find the explanation of a deficiency which has puzzled us in taking an inventory of what she has left behind in her cell. Thus, probably, we shall find a few shreds hanging out of her mouth; and if these are carefully spread out, under the microscope, they will be seen to be fragments of the pupal membrane from the anterior part of the body. The investments of the posterior part only being usually left in the cell. The peeling process is fully completed before the wasp emerges into the dry air, otherwise the membrane would harden, and stick to the parts beneath, so that its removal would be difficult or impossible. As the process of peeling goes on, the insect keeps tearing off and swallowing all that is within her reach. So that if we want to obtain a good specimen of the pupal investment we must not wait till the insect is ready to come forth from her cell, but remove the pupa at a rather earlier period, before the

colours are quite distinctly developed in the permanent integument.

At this earlier period all the lineaments of the future insect are perfectly to be traced, but the limbs look thick and clumsy. With a little care and patience we may withdraw large portions of the covering which gives the limbs this appearance; and the glove, so to call it, bears the exact impression of all the parts beneath. The eyes of the future wasp, the jaws, the antennæ, everything indeed, being as faithfully represented in its cast skin as the eyes and each scale of a snake are in its slough.

For the complete examination of the lining of a cell we must choose one which has not yet been opened, where the round white cap still rises high above the level of the cells, uninjured. By soaking in warm water the cocoon may be drawn out as a long bag, open at the farther end, which, when washed and blown out, and dried, retains the form of the cell. To the unassisted eye it looks like a film of collodion, or goldbeater's skin; but the microscope shows it to be made of threads which have been laid down separately in a wet state, and have run into each other. Its structure is uniform throughout, only it is thicker at the cap end than elsewhere. Cells, where the larva has not yet cast its first skin, like virgin honey-cells, have no lining membrane.

The empty cell can scarcely be said to be quite at liberty as yet; it has to serve another purpose before it is prepared for the next tenant; for the new-born insect often re-enters it, or an adjoining cell, to rest awhile after her exertions. But it is the tail now,

not the head, that projects. The preparations for another occupant are not very extensive. All loose fragments of the lining are cut off, but there is no regular cleansing of the cell, either by wasps or bees; for, as we have seen, the number of the successive occupants may be reckoned by the layers of skin and excreta which they have left behind them, each set in its own lining membrane, and each perfect. The accumulation of these exuviae would soon prescribe limits to the number of times a cell may be occupied, but before these limits are reached the cells are disused. When more room is wanted for the wasps at home, the sides of the old cells, in the upper combs, are cut down, and new brood-cells are built in lower stages, instead of the same being used over and over again. Sometimes, however, it happens that the urgent necessities of a too-prolific queen-mother overrule the convenience of her subjects, and outrun their powers of building. Every cell or fragment of a cell, under such circumstances, will have one or more eggs deposited in it. And we must presume that the wasps instinctively remove the supernumeraries, for seldom, if ever, are two embryos found in one cell.

The time occupied in the maturation of bees,* from the egg being laid to the first appearance of the perfect insect, has been determined to be about three weeks, more or less, according to the sex of the individual. The development of wasps occupies

* See 'Hunter's Works,' Vol. IV. p. 443; also 'Wildman on Bees,' p. 16, and with regard to Wasps, p. 160; and Shuckard *British Bees*, 1866, p. 347.

a longer time. Müller * found that his hornets were five days in the egg, nine days in the larval, and thirteen days in the pupal state; altogether twenty-seven or twenty-eight days, of which half were passed in the pupal state. In two days more they left the nest, mixed with the other workers. Professor Owen † says, that "in the common wasp the larva is hatched eight days after oviposition; it grows to its full size in twelve to fourteen days, then spins its delicate hood, casts its integument, and after a passive pupa state of ten days emerges a perfect insect." From my own observations, I have made no nearer approach to accuracy in this matter than the general fact, that the eggs of wasps take somewhat more than three weeks to develop into perfect insects. Nor can I say at all how long a period each stage of the development occupies, nearer than that, within a fortnight, a nest may be made *de novo*, cells built, and occupied by male pupæ.

The accurate solution of this question is more difficult than may appear at first sight. Speaking generally, winged insects, creatures of the sun, are more observant of seasons than of the duration of time. To them, as to the rest of Creation, ‡ the suc-

* Op. cit., p. 63.

† Owen, 'Invertebrate Animals,' p. 240.

‡ We measure time by the succession of events, and such a measure must vary with the number of events, and the intensity of our observation. And when we speak of a given interval of time, we do not in fact speak of something which is necessarily the same in amount and value for all, but of something which varies in value according to the nature and activity of each.—Thompson's Sermons preached in Lincoln's Inn Chapel, Sermon I, p. 5, 'The Christian's View of Time.'

cession of events is the measure of time, but this succession is accelerated or retarded by the sun, the centre of their existence, as it might seem, the arbiter of their economy. Thus, a queen-bee may either lay eggs within forty-six hours of her impregnation, or, should this not occur till late in the year, she may not begin laying till the next spring. Female wasps, if hatched early in the year, may lay the same autumn,* or, on the other hand, if the season be unfavourable, fertile females may pass over a whole year without building or laying eggs, reserving themselves for a more favourable opportunity.† The possibility of such retardation of the physiological processes, or, under opposite conditions, of their acceleration, to an extent quite unheard of in the higher animals, must be constantly kept in view in all observations on the natural history of insects.

More particularly, adult wasps, although very sensitive of continued wet and cold, and requiring, among the first necessities of their existence, dryness, and warmth, and temporary protection from direct sunlight, are not injured by mere passing changes of weather. The undeveloped brood,‡ however, is very

* 'Smith. 'Zoologist,' Vol. X. p. 3699. V. norwegica.

† 'Entomologists' Annual, 1862,' Smith 'Notes on Hymenoptera,' p. 73.

'Kirby and Spence Entomology,' p. 365, note. "Schirach asserts that in cold weather the disclosure of the imago [of bees] takes place two days later than in warm; and Riem, that in a bad season the eggs will remain in the cells many months without hatching. (Schirach, pp. 79, 241.)"

‡ Dr. L. Möller has made the relation of insects to soil and climate and other physical conditions the subject of special investigation. But his remarks are chiefly applicable to his own neighbourhood,

susceptible of the injurious influences of alternations of heat and cold, dry and wet, particularly when the swarm is too weak to temper these alternations. This constitutes the great difficulty in experiments on wasps, which involve a constant or frequent exposure of the comb. And it vitiates the conclusions from them; for, under such unfavourable conditions the development of the brood may be delayed or entirely prevented. At least this has been the case in all my experiments on this subject, with whatever care they were conducted. Up to the last moment when the new-born insect emerges from her cell the pupa is more or less dependent on the kind offices of her elder sisters. The larvæ, of course, must be wholly dependent on them for their hourly supplies of food. But the pupæ have wants even in their closely sealed cells, which only wasp-nurses can anticipate. The temperature must be attended to, and the atmosphere must be kept at the proper degree of moisture. And for want of hourly attention to these particulars, the experiment will fail, or lead to false conclusions. Sometimes my wasps mildewed, but more commonly they got too dry, and when they did crawl out at last, they appeared with shrivelled wings. They were perfect in all other respects, but quite useless either as citizens or as specimens, with these little black stumps of pinions. The wing could be spread out in warm water, almost

Mühlhausen, and to any insects rather than wasps; so I can only generally refer to them on the present occasion. But I may cite his authority in confirmation of what has been said above of the much greater delicacy of insects in the larval than in any other stage of their existence. 'Die Abhängigkeit der Insecten von Ihrer Umgebung.' 8vo Leipzig, 1867.

to its full dimensions ; it was all there, like the bones in a Chinese lady's foot, but just as useless for all its proper purposes. The wasps soon recovered their warm bath and the affectionate manipulation which was meant to make good specimens of them. The sun brought them out in their true colours—temper and all—and dried off the mealy and sodden appearance of their bodies ; but the wings remained hopelessly crippled, and they were never to be anything more than those useless, dangerous creatures, crawling wasps.

In the history of the entire nest we have already traced most of the history of the individual wasps, living as they do entirely for the community. The new-born insect has but to dry and harden her skin, to rest and gather strength in her newly-acquired limbs, and then, to common eyes, she is lost in the swarm. No one, however, can watch animals long without having something to tell about them, without seeing something by which one wasp differs from another, as one man differs from another, in the doings of ordinary life. The fear is lest this anecdotal natural history should degenerate into twaddle. I trust to avoid this stumbling-block when I come to consider this part of the subject in its proper turn. Just now, I would trace the successive phases of their social, rather than of their individual existence.

The life of a wasp is by no means monotonous ; even in her cradle her future character is foreshadowed by the sharp mandibles with which the larva is supplied, and the courage with which she ventures on

the dangerous journey up the walls of her cell. Her duties are very various; each period of her life has its special duties, adapted to, and indeed resulting from, her physiological condition. The relation in which the mother wasp stands to the swarm is peculiar. She is not to them what the queen-bee is said, by some writers, to be to her subjects, she is merely a well-developed female wasp, their mother rather than their queen. Her history is very like that of the workers in its general outline; they follow, however imperfectly, in her traces. Like her, they build, collect food, and tend the larvæ; and like her—only under very peculiar circumstances—they lay eggs. What we observe in her might be said, with little variation, of any of the undistinguishable swarm.

Hunter,* who entered on the study of bees, as he did everything else, with the feelings of a physiologist in search of the truth, rather than with the complacent wonder which the subject seems generally to inspire, has some very happy remarks on the relations of bees and wasps respectively to their queens.† Speaking of the queen-bee, he says:—

“She is only a bond of union, for without her they seem to have no tie; it is her presence that makes them an aggregate animal. May we not suppose that the offspring of the queen have an

* ‘Works.’ Vol. IV, pp. 429–430.

† Mr. Woodbury, of Exeter, whose name is familiar to every practical bee-keeper, also favours the view that the queen-bee is rather the slave than the mistress of her subjects, her life devoted to laying eggs rather than to politics. It is hard to see how it could be otherwise. See ‘The Times,’ August 6th, or later, 1864, a letter ‘On Bees and Bee-masters.’

attachment to the mother somewhat similar to the attachment of young birds to the female that brings them up? for it is the dependence which each has on its mother that constitutes the bond. When the queen is lost, this attachment is broke; they give up industry, probably die, or we may suppose, join some other hive. This is not the case with those of this tribe whose queen singly forms a colony; for although the queen is destroyed, yet they go on with that work which is their lot, as the wasp, hornet, and humble bee. Most probably the whole economy of the bee, which we so much admire, belongs to the non-breeders, that being their only enjoyment; therefore, when we talk of the wonderful economy of bees, it is chiefly the labourers at large we are to admire, although the queen gets the principal credit for the extent of *their* instinctive properties."

The first change that comes over the mother-wasp is her ceasing to make paper. This faculty, probably depending on the activity of the salivary glands, seems to be given to her, as to the workers, only for a time. For should the early brood, as in an instance presently to be narrated, be only drones who cannot, or at least do not, continue her work, after a certain time the growth of the nest ceases. In the ordinary course of things, however, by the time she is exhausted the worker brood has begun to appear, and they relieve her of this part of her task, and of the daily increasing labour of feeding the larvæ. She restricts herself henceforth to her purely maternal duty of laying eggs and, as her increasing size makes almost a matter of necessity, now rarely leaves the interior of the nest. Brood

after brood successively undertake the task of building, replacing the older wasps which, like their queen, are past the age for making paper. Thus a constant system of promotion is going on, those which have no longer the faculty of house-making betake themselves to the duties of house-keeping, and while the large young wasps, in full glandular vigour, maintain and enlarge the nest, the older shrunken wasps find full employment in satisfying the hungry mouths which peer out from the lower surface of the combs.

While, under this regular system, the swarm is thriving, and fulfilling the duties of wasps by destroying a vast amount of insects—even more noxious than themselves some would say—and of rotten wood, preparation is made for the perpetuation of the species. The drones or male-wasps, and the perfect females, now make their appearance. The cells in which both of these are bred are taller and larger than the worker cells, especially those of the perfect females. Sometimes one of the lower combs is composed entirely of queen-cells, or a zone of these larger cells may be seen in the ordinary comb, their tall white domes overtopping the humbler abodes of the worker brood. It is said that these cells are never used more than once.* This statement is made on too good authority to be questioned, but the fact admits to a certain extent of explanation by the circumstance that when the male and female brood appear the season is advanced, and the store of eggs of the queen well nigh exhausted.

The appearance of the males and females indicates

* Smith. 'Catalogue of British Hymenoptera,' 1858, p. 214.

a coming change, but does not bring any present alteration in the domestic arrangements of the nest. For the young females in a wasps' nest, unlike those in a beehive, live very amicably with their mothers and the rest of the swarm. Which is quite as well, as they are not hatched by one or two, but by dozens, at a time. They do not appear to work, as they are not seen flying in and out of the nest, or gathering food or materials for building. They rather cling to the inside of the nest, not leaving it, even when it has been taken, till long after most of the workers have been frightened or shaken out. They are very sociable among themselves, being found hibernating in large parties, beneath the bark of a tree, or in a hole in a bank. So, too, with the drones. They are so many added to the number of unproductive mouths, for they do nothing, as far as I have seen, for the public service. Though, as their salivary glands are fully developed, there is no apparent incapacity for making paper. But, if they do nothing, they cost little or nothing. For their bodies are loaded with fat; and as they must be intended to consume this during their short lives, the quantity of food they require besides their own stores must be very small indeed. They are tolerated and fed ungrudgingly; and when they leave the nest they go out of their own accord, and are not hunted out, like their bee cousins. Thus much, however, must be said in detraction of the wasp's superior courtesy and hospitality, that the drones have no inducement to remain in the empty nest to starve, and that they take their departure with all the rest of the swarm.

The name of drones is ill applied to them, for they are always flying about, and, however little may come of their work, they are always busy—*sedulâ inertia*.

Regardless of their presence, the business of the nest still goes on, day by day, the same unwearied industry continues, without intermission. So long as the queen lays eggs, so long as there are larvæ to be fed, or wasps which can build, so long the swarm continues to work in active harmony, and the nest grows. But the end comes at last, and perhaps all the sooner when a bright sun and a good harvest of plums have supplied most freely the necessaries of wasp-life. The very favourable season, by increasing the activity and vitality of the swarm, may itself hasten the end. A nest may be found deserted before the summer has closed, before the cold and wet, the natural enemies of wasps, have set in, simply because the queen is prematurely exhausted, has lived, in fact, too fast. But, whether the wasps have straggled away from a feeling that they have no longer anything to do, and that in the loss of their work they have lost the tie which bound them to their busy home, or whether they have been killed by the wet and cold, the end in either case is sure. The swarm is dispersed and the delicate fabric is left as a covert or a prey to hardier insects; for so long at least as it holds together and resists the wind and rain of autumn.

Sometimes a storm scatters the swarm and the results of all their labours to the winds. But, when a more gradual process of dispersion has left us the

nest to examine, we find that, to the last, the wasps were still preparing to extend their house in strict conformity with the instinctive rule,

*Servetur ad imum,
Qualis ab incepto processerit, et sibi constat.**

A little central comb is to be seen at the lower part of the nest, and the builders of cells are just a little in advance of the layer of eggs. As the beginning of the nest was determined by the physiological condition of the young fertile queen and the young workers, so, unless physical causes interfere to bring about an earlier dissolution, is the end. When, at last, the ovaries of the parent wasp are exhausted, when there are no young workers to make paper, and no brood to be fed, then the common bond which held the swarm together is loosened, and the wasps straggle off, one by one, never to return.

Late in the summer, when wasps are plentiful, the grass swarms with them, they fly listlessly along the ditches, or establish themselves permanently on the fruit-walls. To say nothing of those which take up their quarters on the wrong side of our windows, or make more direct personal advances. Now, I have nothing to say on behalf of these wasps. They are a nuisance, and a terror to all who have little children. They are mere stragglers, who have lost all feeling of good fellowship, have deserted their nest, and are leading a freebooter's life. But the wasps which we see flying about earlier in the year are not leading, by any means, a life of selfish indolence. As a little observation of their habits

* Horace. 'Ars Poetica,' 126.

will show. A sip of water here, a scraping of wood or grass there, as the passing opportunity may offer; as busy, but not so fussy, as bees, these wasps are engaged actively in social duties, while they seem to be merely amusing themselves like flies. Once laden, inside or out, they fly straight home, and near the nest no stragglers are to be found. They go straight in or out, and do not haunt the immediate neighbourhood of their home. From several nests which have worked in my windows on different occasions I never found but one straggler within doors, and she had evidently lost her way, and had come in from the other side of the house.

The same fate, however, awaits them all, idle and industrious alike. A few rainy days and cold nights, and it is all over with them. With great care, keeping them warm and clean and well fed, and exposing them to the sun as tenderly as a cottager does her auriculas, once I managed to keep a swarm of *V. germanica* alive to the end of January; but they all died at last.* The age to which bees, and particularly queen-bees, may attain has been very variously stated,† but the limits of a wasp's life are precisely known. The workers and drones, with every care, will not survive the winter, and the length of the queen's life does not exceed a summer and a half under ordinary circumstances. Though, should anything have prevented the queen from building her nest and laying eggs, there is reason to believe, as

* Zoologist, Vol. XVII, p. 6655, 1859. 'Contributions to the Natural History of the British Vespidae.'

† This subject is discussed at length by Mr. Desborough. 'Entomological Transactions.' Vol. II, New Series, p. 145. 1852-3.

already stated, that she may pass over a year, and not build till the third summer. Like all other insects, however, she dies when she has effected the great object of her existence, namely, the perpetuation of her species. Only by deferring the accomplishment of this object can her life be prolonged. "We term sleep a death; and yet it is waking that kills us, and destroys those spirits that are the house of life."* Yet these spirits, or, as we call them in modern physiology, the vitality, of the queen-wasp would scarcely preserve her life for so many months without the necessary fuel. She would die, if the wear and tear of her body were not reduced to a minimum during her long torpor, and if she had not a large supply of food laid up in the fat mass of her abdomen, to make her independent of the winter storms which rage outside her hiding-place.

The proceedings of a swarm of wasps are more easily explicable on ordinary physiological grounds than those of a hive of bees. From the moment it has been determined that this or that bee-larva shall be developed into a perfect female—a queen-bee—there is a mystery about the insect which only those who have made bees their peculiar study, and have an intuitive knowledge of all that is going on in a hive, can rightly appreciate. I have had no such opportunities of studying, and have no such intuitive knowledge of bees; I can only accept on the authority of others what is said of the almost reason which directs all their proceedings, which regulates the proportion of

* Browne, 'Religio Medici,' II, §12.

the sexes, which determines the division of the swarm, and presides over all the internal economy of the hive. But with regard to the queen- or mother-wasp, the story is told in a few words, and without any mystery. Let me recapitulate, as briefly as possible, from a physiological point of view, the history of a wasp's nest:—

In the height of the summer, when the swarm is strong and food is plentiful, when in short, so to say, the whole concern is thriving, the well fed larvæ develop into females, full, large, and overflowing with fat. There are all gradations of size, from the large fat female to the smallest worker, to be found in the swarm. All, even the smallest, may perhaps have distinct ovaries, with eggs in them, capable of being displayed by a lucky dissection. But the larger the wasp, the larger and better developed, as the rule, are the female organs, in all their details. In the largest wasps, which are to be the queens of another year, the ovaries differ to all appearance in nothing but their size from those of the larger worker wasps. At this season of the year the bulk of their abdomen is not made up of eggs, but of fat, which has its purpose in supporting life through the winter, till such time as the ovaries, with their increased size, shall assume their active functions. When there are plenty of wasps to build, with abundance of the best food, and plenty of wasps to bring it in, the larvæ are fed up to the highest point, the cells are built to suit the dimensions of the luxurious thriving grubs, and a brood results, which are fat, well developed, perfect in all their organs, and only needing impregnation to enable them to reproduce their

species in both sexes. Small feeble swarms produce few or no perfect females; but in large strong swarms they are found by the score, larger or smaller, more or less perfectly developed, more or less laden with fat. And, if the same rule holds for wasps as for bees, the more perfect the insect is the greater is the rapidity with which it is developed. Lastly, from whatever cause, whether from a voluntary act of the queen wasp, as of the queen bee, or as a simple consequence of having laid so many eggs, the last eggs are deposited without being fertilized, and drones are developed from them.

By such very simple means the perfect and imperfect females are fitted for the lives they have to lead respectively. A perfectly organized female without a supply of fat could hardly survive her winter sleep and her spring toils. A fat worker might survive the winter, but would be unable to continue the species, in both sexes, in the ensuing summer. The fat serves its present purpose, and, as it is used up, its place is more than occupied by the enlarged ovaries of the queen-mother who—unless the hornet be an exception to this rule—is henceforth almost compelled, by her unwieldy size, to remain a prisoner within her own nest.

And now to venture into the domestic privacy of wasps. If we wish to study the habits of wasps, to become more closely acquainted with them than the mere external examination and the occasional capture of a nest will allow, we must secure a swarm with its nest in active work, remove it to some place more convenient for observation than wasps usually select,

and expose the comb freely to view. The most convenient situation is a window ledge, where, under the shelter of a box without a lid, set up on end, the wasps will work as freely as in their more familiar quarters. It is advisable, before establishing the colony there, to see that the sash runs easily and without noise, that we may be able to look with our fingers, as they say, now and then, without irritating the swarm needlessly. It requires a little courage and skill to execute their removal successfully, but, once effected, the spectacle is one of constant varied interest, certainly not surpassed by that of a swarm of honey-bees ; while from the smaller number of the insects their proceedings are much more easily intelligible.

Busy as wasps always are, yet a wasp's nest does not present such a scene of universal ceaseless industry as a bee-hive. The stream of life passing in and out is not so strong, and wasps may often be seen, especially in autumn, lying motionless, or slowly crawling over the case of the nest. However, even honey-bees seem indolent and indifferent sometimes, as, for instance, when they are wandering by twos and threes over a new glass which has lately been added to their establishment, and of which they have not yet fairly taken possession.

Supposing the removal of the nest and the exposure of the comb to have been successfully accomplished, the wasps will settle down to their work in a few hours. After watching for a little while we find that the wasps coming into the nest are divisible into two classes, one laden with materials for mending the injuries which the nest has suffered, the

other bringing food for the young brood. As we have already closely examined all the details of the process of building, we need not dwell any longer on these now; but, while the wasps still have any of the interior open to view, we may turn our attention to other points of their domestic economy. And first of their food.

Wasps' food is of the most varied kind, they eat fragments of meat, the bodies of insects, fruit, garbage, anything, in short, from which nourishment can be extracted. But it is the nutritive fluid which is extracted from these various bodies that they consume, rather than the solid substance itself. It is true that fragments of the harder parts of insects are sometimes found in their castings, and generally form a large portion of the contents of the intestinal pouch of the larvæ; still, as a rule, wasps live on fluid food.

When a wasp appears with her crop full of fluid, she becomes immediately a centre of attraction. Two or three gather round her, and take up the fluid as she gradually lets it drop out on the upper surface of the comb. Then the larvæ are visited in their cells, and take their food in the most sisterly way, from mouth to mouth, till the supply is exhausted, and the nurse is at liberty to go away and replenish her crop. The solid food which is brought in cannot be so easily distributed, but, however it is portioned out, there is never any quarrelling. Strong as the instinct is in wasps to snatch and hold their own against all the rest of the world, yet no feeling of resentment seems to be aroused by the loss of their prey. Once gone, whether to friend or foe, it is lost,

and they make no angry attempts to recover it. The distinction of *meum* and *tuum* has no place in a wasp's feelings, any farther then her mandibles can reach. Right and might are to her exactly the same thing, and she who has lost is just as if she had never possessed.* Their common nest only excepted.

Wasps' nests are not free from intruders; snails, and the larvæ of different insects, are sometimes found in them. As far as circumstances will allow they are kept scrupulously clean; the tree-nests most particularly so. The excretions are discharged outside the nest; all the dead grubs, and all rejected fragments of food, are carried away to a distance. The refuse of a nest of *V. germanica*, which I kept in a glass case for many weeks, was always removed in this manner, and the grubs were usually stuck up on the panes, at the extreme boundaries of their range, as it were, by the workers. In the same way ground-wasps remove to a distance all they can of the earth and stones which they excavate from their dens. The limits to what they carry away are of course very narrow, as they can only support a very little weight in the air, though they can drag large and heavy bodies along the ground. Probably, it is the smooth, polished margin of the hole which betrays the wasps' nest beneath, the grains of earth and fragments of insects are generally too widely scattered to give any clue to the position either of

* Hunter, Op. cit. p. 426, gives bees the same good character, they are not covetous or disposed to obstruct others, but what they have collected they defend.

the tree- or of the ground-nests. But where the ground is stony, the entrance is marked by a heap of pebbles, which the wasps have pushed up from beneath thus far, but could not fly away with.

I have met with an illustration of this which is worth recording:—The entrance to a very strong nest of *V. vulgaris* was encumbered with a heap of such little pebbles. On an average, each of these weighed 1.85 grains. They were all of very nearly the same weight, so uniformly, indeed, that it seemed as if no stone heavier than two grains could be got out of the hole, and all lighter than one grain could be carried away to a distance. When I returned to the nest some weeks after, this conclusion was confirmed by finding the larger pebbles forming a bed of gravel at the bottom of the den. Each of the stones at the pit's mouth seemed to represent the power of a single wasp; for wasps, unlike ants, labour singly; so the stones which one wasp cannot lift lie at the bottom of the nest, and the snails, which one wasp or bee cannot drag out are papered or waxed up when they die. Though a little combined exertion, such as ants or beetles would have applied, would have effectually removed the nuisance from their doors.

An ant or a burying-beetle would have solved this problem. Another, as Mr. Prince, of Uckfield, has reported it to me, would probably have surpassed even their ingenuity. A butcher often revenged himself on the wasps which stole his meat by clipping their wings. Long practice, with a sharp pair of scissors, had made him so dexterous that he could snip off a wing without interrupting the wasp

at her work. When the wasp had cut off a piece of meat she tried to fly away with it, but finding she could not fly, thought the piece was too large to carry, and cut it in half, and so she went on cutting the meat smaller and smaller, as long as the butcher would let her, attributing her inability to fly to the size of her burden, not to the mutilation of her wings.

The private life of a wasp, as of a prime minister or the member for an inflammatory borough, is chiefly occupied with eating, sleeping, and moving from place to place. Like these dignitaries, the wasp is entirely spent in the public service. We have already spoken of the eating and of the mode of flight; a notice of the sleep will complete all that is to be said on this topic.

All animals, even wasps, sometimes rest, if they do not sleep. Wasps may be seen lying out on the nest by day; but their position here indicates rather vigilance than rest. In the night they may be seen standing on the comb with their legs stretched out behind them, or they thrust themselves, head foremost, into empty cells. The torpid queen arches up the back of her abdomen, and folds her wings closely by her side. And there she stands for months, a picture of helplessness, her sleep only distinguishable from the quiet of death by the regular feeble respiratory movements. Sometimes wasps prowl about, in or on the nest, at night; but the smaller wasps do not work at these hours, indeed their work is generally finished in the afternoon. Hornets,*

* Smith. 'Catalogue of British Aculeate Hymenoptera,' p. 222. 1858. Wood, 'Homes without Hands,' p. 438.

however, work by moonlight. As a rule this species keeps less regular hours than the smaller wasps, and is not at all particular about being at home at night. So many of them are out of the nest at this time, that a night attack on hornets, however well conducted, is not usually as successful in exterminating the swarm as a raid on wasps after dark.

The usual end of wasps is by cold, wet, and old age. They seem, however, to be liable, like bees, to epidemic diseases, though I am not aware that their maladies have been studied as carefully as those of the more valuable insects. Honey-bees are known to suffer both from obstruction of the bowels and a kind of epidemic dysentery: they suffer also from at least two species of Entozoa—namely, *Gordius* and *Sphæricularia*.* The same Entozoa occur in wasps. It is strange that parasites of so large a size should be found in so small a space as that which the abdomen of a female wasp offers. The *Gordius*, which I have met with only once, a female, seemed to cause great distress to its “host.” The abdomen of the poor wasp was distended as if she was about to become the mother of a swarm, and she was constantly straining to rid herself of her burthen. She was only recently hatched, and could scarcely have ever left the nest, yet she had within her abdomen a parasitical worm more than thirty lines long. The presence of the *Sphæriculariæ*, which I have more frequently met with, and of both sexes, apparently gave rise to no symptoms, for it was quite by acci-

* Lubbock on *Sphæricularia Bombi*. ‘Natural History Review,’ Vol. I, p. 44; Vol. IV, p. 265.

dent that I happened to select the wasps in which these were found for dissection.

In tropical countries wasps suffer much from fungous excrescences growing from their spiracles; crippling their movements, and ultimately destroying life. I have never seen these in English wasps; but a similar disease, under the name of muscardine, is very destructive to silk-worms, and what is of much less importance, to house-flies, in autumn. The fungous excrescence of the wasp seems, however, from De Saussure's figures, to be a much more substantial growth than that of the house-fly, or the silk-worm. In all these instances the spores of the fungus, *Botrytis* or *Sphaeria*, as the case may be, gain admission through the spiracles into the air-passages and germinate there.*

* See 'De Saussure Guêpes Sociales,' Chap. IX, for an admirable summary of what has been observed on this subject; also 'Planches' V, fig. 9; XI, fig. 5. Also, Carpenter's 'Principles of General and Comparative Physiology,' 2nd ed., § 97; and Berkeley's 'Introduction to Cryptogamic Botany,' 1857, p. 237. *Sphaeria Robertsii*, growing like a horn from a New Zealand caterpillar, is figured in Lindley's 'Vegetable Kingdom,' 2nd ed., p. 40.

CHAPTER IX.

EXPERIMENTAL INQUIRIES.

RESULTS OF THE DESTRUCTION OF THE NEST. OF THE REMOVAL OF THE
QUEEN, EXPLAINED BY PARTHENOGENESIS.

THERE remains yet another phase of the History of Wasps, as interesting in a physiological point of view as any which may have preceded it, though commencing at a period when many might suppose that the misfortunes of the swarm which had been so unlucky as to become the subject of scientific experiments had been finally consummated by the capture of their nest and the death of the queen. Every little boy however knows that the mere destruction of the nest is not always followed by the extermination of the swarm. Indeed at first it might often seem that nothing is gained to the neighbours by the operation; for the nest is soon replaced, and the wasps are crosser than before. Even the additional calamity of the loss of the queen may at first produce no sensible difference. The swarm does not go wandering in search of their lost mistress, they do not hang mournfully on the hedge. On the contrary, they eat, and work, and sting, to all appearance, the same as ever; just as if nothing whatever had happened. But, if we watch a little more

closely, we shall find reason to change the opinion which we had hastily taken up. And the double calamity, the loss of the nest and the loss of the queen, opens two distinct branches of inquiry. First, we find that the nest, as rebuilt, resembles the former nest only externally. And next, the swarm without its queen, however strong, and fierce, and industrious it may be, contains within itself no bond of permanent union.

And first with regard to the nest:—

As soon as the irritation and confusion consequent on the removal of the nest have subsided, the instinct of the surviving wasps resumes its sway, and they set about making a new nest, either on the site of the old one, or in its immediate neighbourhood. This process may be repeated as many as three or four times, according to the strength of the swarm and the habit of the particular species. As fast as one nest is removed or destroyed it is replaced by another nest. Each of these successive nests bears more than a mere generic resemblance to the original structure; the peculiarities of the preceding nest being in some sort reproduced. They do not however pass through all the same stages as the original fabric in their development. For they are built up at once, on the scale, and outside plan, of that which has been removed. And this fact necessarily involves some important differences in the details of their construction. For instance, the upper part or crown of the nest is not made of the remains of older structures worked into each other, but of distinct sheets of paper, closely applied one over the

other. I have seen a secondary nest of *V. britannica*, the species on which these observations were chiefly made, with as many as eleven successive layers thus disposed. Again, the new comb differs from the original structure. The formation of the cells is less regular, and the stages are arranged differently. Instead of the case being filled with these, closely packed one below the other, the stages which it contains, one, or at most two, have a large unoccupied space below them. In fact, the usual order has been reversed, the comb was made to go inside the case, as the work went on hurriedly and irregularly, and not the case to cover the comb. And the resemblance, which appears on the surface, does not enter very deeply into the construction of the nest.

Each time that the nest is replaced it differs more and more from the original type. It becomes smaller, less shapely, and has less pretensions to anything like a regular comb within. After it has been destroyed three or four times, the survivors make no further attempts to replace it. Perhaps some little scraps of paper, forming a hood over half-a-dozen cells, represent the last efforts of the diminished swarm. Some few wasps will haunt round this, day after day, till, as their numbers decrease, only three or four workers are left as the guardians of as many abortive larvæ, or a heavy shower puts an end at once to the struggles of the colony.

I have in my cabinet a series of nests,* made by one swarm of *V. britannica*, the successive specimens indicating the failing strength of the survivors of the successive operations. The second is made of the

* Plate XIII.

same size and to nearly the same pattern as the first nest, corresponding to the energies of so many paper-makers suddenly thrown out of employment. This is succeeded by a much smaller one, which still however reproduces some of the chief features of the original structure; and it is still obviously a wasp's nest. But the last in the series consists merely of a few scraps of paper gathered on a neighbouring twig, looking just like an old grey rag which had been caught in the bushes.

While the wasps which have been left in possession of the site are thus occupied, those which have been removed to another situation, along with the original nest, may have also established themselves, so that the swarm is possibly divided into two active colonies. Whether from the shaking they have undergone, or from whatever cause, the wasps which have been thus transplanted seem to have a feeling of insecurity, perhaps not wholly unnatural under the circumstances, and often attach the comb to the outer case of the nest to strengthen the fabric. But they will continue their labours in their new situation, if they are only prevented from straggling away in search of food, during the first few days, while their numbers are few and the neighbourhood is strange.

Sometimes a swarm will divide into two, as the result of an accident. Thus, in one case, where the sticks in a hedgebank prevented my taking a secondary nest of *V. sylvestris*, which had got entangled among them, the unsuccessful attack caused the division of the nest into two portions, which became henceforth separate establishments. Conversely, two

swarms will sometimes combine together, either, as we have seen,* from the fellowship of a common misfortune, or as the result of experiments such as Professor Edgeworth† has so ingeniously contrived. And this, whether the wasps be of the same or of different species.‡

The courage and endurance of *V. britannica* are conspicuous under these trying circumstances, while *V. rufa* is said§ to be singularly wanting in energy under this calamity, and to make no attempt to repair the injury. The workers, in such case, are unworthy of their queen, who seems to be quite an Amazon among wasps. For, whenever a female of this species has been sent me in a box with other live females, *V. rufa* has generally contrived to murder and mutilate her travelling companions.

. These experiments may be varied to any extent; and, by directing their labours, by means of threads and wires, wasps may be made to build in the most grotesque forms. But I need not dwell on these; for whoever has seen the results of Mr. Stone's|| curious experiments in wasp architecture in the British Museum, will scarcely need any further illustrations of the various shapes which their nests may be made to assume. And we may go on at once to the second part of this inquiry, namely, as to the effect of the loss of the queen on the swarm.

* Page 203.

† On Irish Vespidae. 'Annals and Magazine of Natural History,' 3rd Series, Vol. XIII, p. 470.

‡ Mr. Stone. Wood. 'Homes without Hands,' p. 361.

§ Edgeworth, op. cit., p. 472.

|| See also Wood. 'Homes without Hands,' p. 358, and Plate.

In the first instance, as far as concerns the rebuilding of the nest or the continued care of the larvæ, it seems to make little or no difference to wasps whether they have their queen with them or not. For a time the loss of the queen-mother is not felt so much by wasps as by bees, and the swarm lives and works on as if nothing out of the usual course had happened. But while honey-bees can, within a certain number of days, replace their lost queen, to wasps the loss is irreparable. A newly-hatched larva of the honey-bee, put into royal training, emerges as a perfect female in less than thirteen days.* Meanwhile the expectation of her arrival keeps up some system and diligence in the hive. Within forty-six † hours of the time she has paired, she may begin to lay eggs, so that, after an interruption of little more than a fortnight perfect order is restored, and all goes on again just as before.

With wasps, however, it is quite otherwise. To them the loss of their queen, unperceived at first, is the dissolution of their society.

It is the little rift within the lute,
That by and by will make the music mute,
And ever widening slowly silence all.

There are plenty of more or less perfect females which lay eggs as soon as cells have been built to receive them, so that before the new queen-bee could have begun to lay at all, the eggs of the worker wasps would have become pupæ. But these eggs produce only male brood. After the loss of

* Kirby and Spence, op. cit. p. 365.

† Ibid., op. cit. p. 374.

‡ Tennyson. 'Idylls of the King.' Vivien's song.

the queen no more females, perfect or imperfect, are produced. And, for want of a continued supply of these, the swarm languishes and fails, and the nest is ultimately deserted, the queen never having been replaced in her full maternal capacity.

The explanation of these facts brings us to a subject on which the state of our knowledge is not as yet precise and positive enough to allow us to dispense with the details of observations and experiments. We cannot yet assert with certainty that the conclusions of Siebold as to Parthenogenesis* in the honey-bee are applicable, without any qualification, to wasps. From my own more recent observations, some of which I have subjoined, I think that this principle is applicable to wasps as closely as to bees, but I must own formerly to have been inclined rather to a contrary conclusion, for want of allowing sufficiently for the retardation of development under unfavourable circumstances.†

In the discussions which have been incidentally introduced in the course of this work, the thought may have intruded itself on the reader that some of the subjects discussed had no nearer connection with wasps than with any other insects. The theory of flight, for instance, and the source of the sound which insects make, might have been investigated, perhaps, just as well in connection with flies as with wasps. But the subject of Parthenogenesis is spe-

* Siebold, 'On a true Parthenogenesis in Moths and Bees,' translated by Dallas. 8vo, London, 1857.

† The history of this nest formed the subject of a communication to the 'Zoologist,' 1858, Vol. XVII, p. 6641.

cially connected with wasps. The principle has been clearly explained, in its application to the honey-bee, by the researches of Siebold and Dzierzon; but it remains for other observers to extend it to other families of insects. And the natural history of wasps needs this light on some of its more obscure chapters. The theory of Parthenogenesis in all its details could hardly be compressed within the limits of this chapter; and I must refer those who would master it fully to Siebold's work, where the accurate observations on which it has been founded are recorded at length. It will be enough here to recapitulate the general conclusions from these observations.

The fact has been established, beyond doubt, that the sex of the future honey-bee depends on whether the egg has been fertilized or not on its passage from the ovaries. Fertilized eggs produce females, which are perfect or imperfect as the subsequent nourishment of the larvæ may determine. Eggs which have not been fertilized produce only males; and a female bee, which has not been impregnated, from her inability to fly or from whatever other cause, can only lay drone eggs. The close attention which has in all ages been devoted to honey-bees had led bee-keepers long ago to the conclusion that a morbid condition of the queen bee often prevented her producing anything but drone brood; but a scientific inquiry has raised this general inference to the dignity of an established principle.

Now let us apply this principle to explain the results which regularly ensue, in a swarm of wasps, on the removal of the queen. When she has been taken with the nest, and the swarm has been left to

re-establish itself without her, as it best might, the new brood has, to my experience, uniformly consisted of drones. The wasps which build the secondary nest, and deposit in the new cells the eggs which develop into drone brood, are nothing more than the common workers of the original nest, whose ovaries have been stimulated into activity by the removal of the queen. When the swarm is numerous, we cannot of course observe each individual accurately, and feel sure that such and such only have been engaged in the work. But the case is different when the swarm has been so weakened that we can count, we can mark if we like, every one of the labourers. The structure may, indeed, under such circumstances hardly deserve the name of a nest; but the wasps are all the more open to observation on this account.

Three such abortive nests were watched very carefully, while they were being built and the wasps were employed about them; and it appeared certain that they were made and inhabited only by ordinary workers. For no other wasps were ever seen about, and no others were found in them when they were taken at last.

The interior of two of these nests displayed a few cells with eggs, while the third, the most deserving of the name of a nest, contained diminutive larvæ. These larvæ, however, though they were left undisturbed for a month in the place which the wasps had chosen for themselves, during the most favourable weather, and with their own nurse tenders to look after them, still remained diminutive larvæ, never even reaching the pupal stage. None of the passengers whirled along the railway knew what a

physiological problem was being worked out in the hedge, near Hassock's Gate Station, and fortunately no little boys knew of it either. So the nest hung on safely, till it was clear that no further change was being made in it: and, then, I stopped all the apertures with cotton wool and cut the spray to which it was attached. When it was brought home and examined only two wasps were found in it. These were, to all appearance, common worker-wasps, even of less than the average size; but, on dissection, they were found to contain distinct eggs and traces of the ovaries, which were demonstrated with less difficulty than usual.

The failure of the development of these larvæ, as of those which I have tried to nurse to maturity myself on several occasions, seems to have resulted from a state of things just the reverse of that under which large perfect females are reared, by the score, from eggs which in the earlier summer would have produced only common workers. They had scanty food and imperfect attendance; and so they pined, as little babies often pine and dwindle away under similar circumstances.

Sometimes Nature, as it were, makes these experiments for us herself, and we have only to interpret the results. I have in my cabinet a large nest of *V. britannica* which was taken in the hot summer of 1864. When it was first discovered, the swarm was so very strong in numbers that my sister, with all her skill and courage, declined to attempt its capture. After not many days, however, it was found to have been entirely deserted. The singular mode of construction of the lower comb represented

in the drawing,* shows that some unusual influences had been at work. Instead of one comb, built of cells of uniform size, spreading regularly from the centre, there are five patches or tufts of cells of all sizes and of the most irregular construction. Mr. Stone,† who has described a similar appearance in the nest of another species, *V. vulgaris*, has suggested an explanation of it in the ill-directed efforts of a queenless swarm:—"The interior presented an appearance so unlike the interior of one over which a queen presides that I at once felt convinced no queen had ever set foot in it. No order or regularity was observed in the disposition of the combs; small ones, to the number of seven, were to be seen stuck about here and there on the face of the original one, from which they depended, while the cells were crowded with eggs or small larvæ, one cell containing as many as sixteen eggs, and but few less than five or six. The colony . . . consisted exclusively of workers, and they rather under than over the average size."

In Mr. Stone's specimen the greater part of the original nest had been destroyed, and with it the queen had perished. In mine the nest was not injured, but the queen seems to have been removed by her death, or by some accident. In either case it was the removal of the queen which lay at the bottom of the singular malformation of the comb. The swarm went on building irregularly without any fixed plan, till, in the absence of any common bond, they finally straggled away. There must have been plenty of

* Plate XIV.

† 'Zoologist,' 1860, p. 7263.

young females in the nest, many of them probably impregnated; and their inability to supply the place of the queen-mother at once is particularly worthy of notice.

Here the swarm had thriven, and the nest had grown even beyond the ordinary dimensions of such structures. Another specimen in my cabinet takes up the story at a different point. For this I am indebted to Mr. Prince, of Uckfield. A gamekeeper in that neighbourhood, instructed to be on the lookout for anything in the wasp line, reported, in June, 1865, a nest of wasps of a kind quite new to him, and before many hours had elapsed the nest, swarm and all, was safe on my study table. This too, was the work of *V. britannica*, about three inches in diameter, well proportioned, and very neatly made; but it contained only drone brood in the cells, and all the swarm were drones also. Apparently the queen had only laid male eggs from the beginning; and, getting no help from her sons, she had deserted them.

There is no more reason to doubt that the worker wasps, in the absence of their queen, lay eggs than that they build nests. Not only in abortive or secondary nests, but in regular nests, which no Naturalist has disturbed, we may find eggs in the ovaries of the common workers. Eggs and ovaries, indeed, are not always to be found. We may examine many specimens without finding any eggs at all, or even without distinctly tracing the minute ovaries. And the size of the insect is no certain indication of their presence; eggs occur in the smaller as well as in the larger workers. But where eggs are they only need some particular stimulus to call them forth.

The physiological difficulty, however, is not here; there is no mystery about the maternity of the eggs; for we constantly find, even in the higher animals, that eggs may be laid without impregnation. This, as is well known, is the rule in fishes and some reptiles. Its occurrence in birds is familiar to poultry-keepers; and a parrot confined for years in a cage occasionally presents her astonished owner with an egg.* The curious thing is that the removal of the queen-mother should at once stimulate the imperfect ovaries of the workers into activity, that eggs laid under such circumstances should hatch at all, and that hatching they should produce drone brood only.

Whenever I have had an opportunity of examining the comb of a secondary nest, built after the removal of the queen, I have invariably found whatever pupæ it might contain to be of the male sex. This fact, inexplicable on other grounds, is at once explained on the principle of Parthenogenesis as laid down by Siebold. And, as far as my own observations go, I have every reason to believe that wasps conform to this law generally in the same way as honey-bees. But this whole matter still needs examination by other observers and by different modes of inquiry; for, apart from the general facts, there are other questions waiting solution. For instance: Is it certain that the workers do not ever lay eggs when the queen is with them? and, in such case, what becomes of these eggs? Again: remembering that the last laid eggs of the solitary bees produce males,† how far is the

* 'Harvey's Works,' translated by Willis, Sydenham Society, p. 186, contain the fullest information on this subject.

† Wood. 'Homes without Hands,' p. 179.

principle of the exhaustion, not the voluntary action, of the queen determining the sex of the brood founded in fact?

Such questions might easily be multiplied, not only as relates to the subject immediately under consideration, but on many other points of the Natural History of Wasps. And if I leave off now, it is not because I have told all their story, even what my own notebooks tell, much less what other books and further observation could, and I trust will, show. It is because the wise man says,* "Withdraw thy foot from thy neighbour's house, lest he be weary of thee, and so hate thee."

* Proverbs XXV, 17.

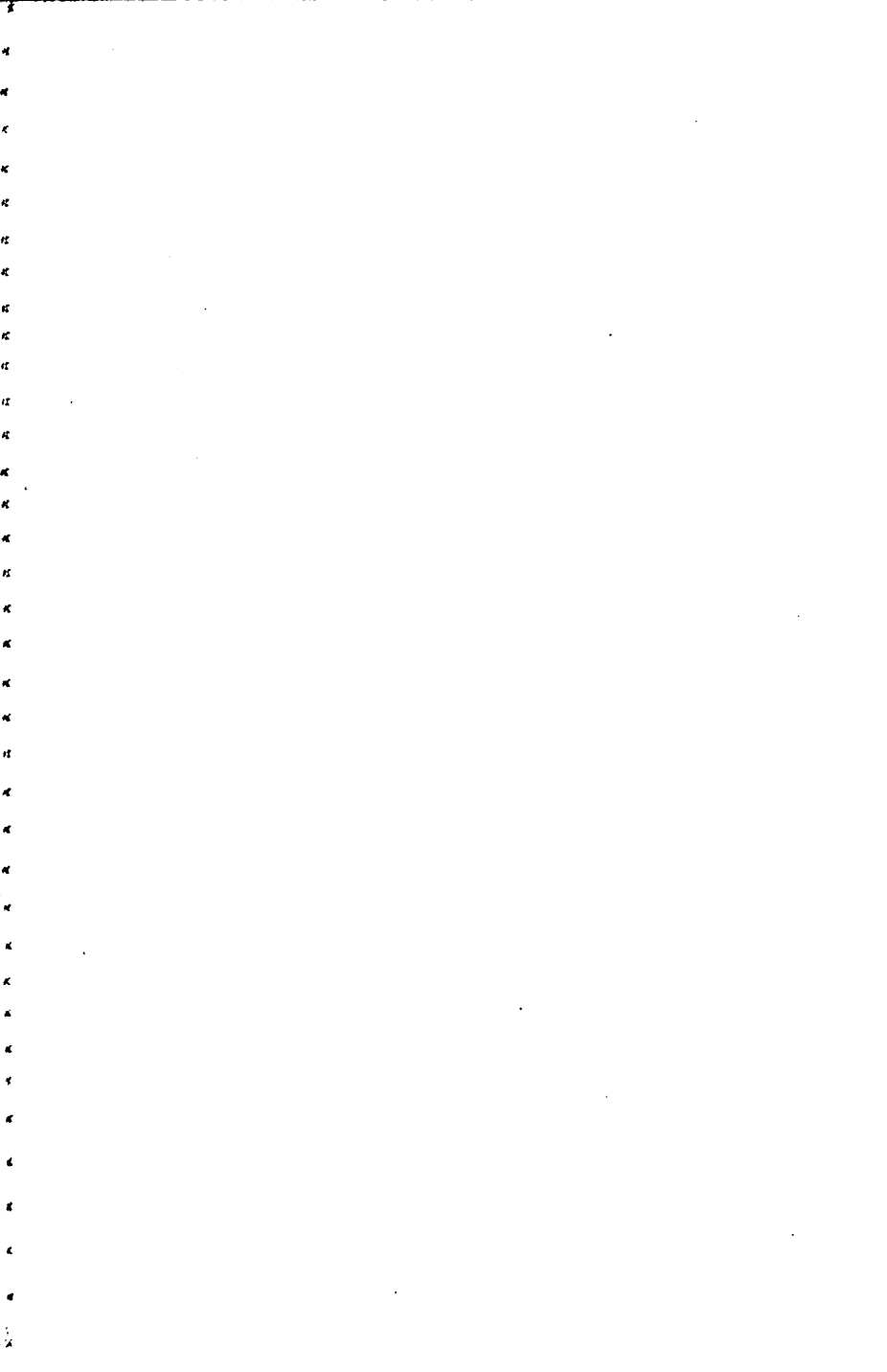
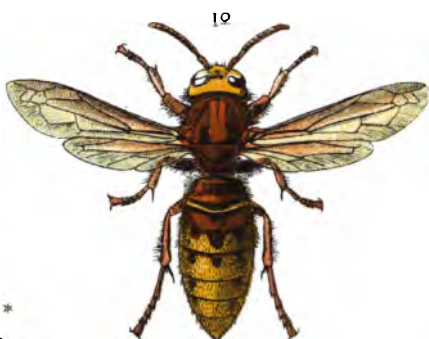
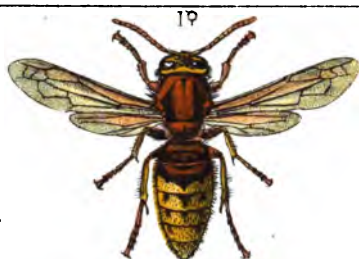


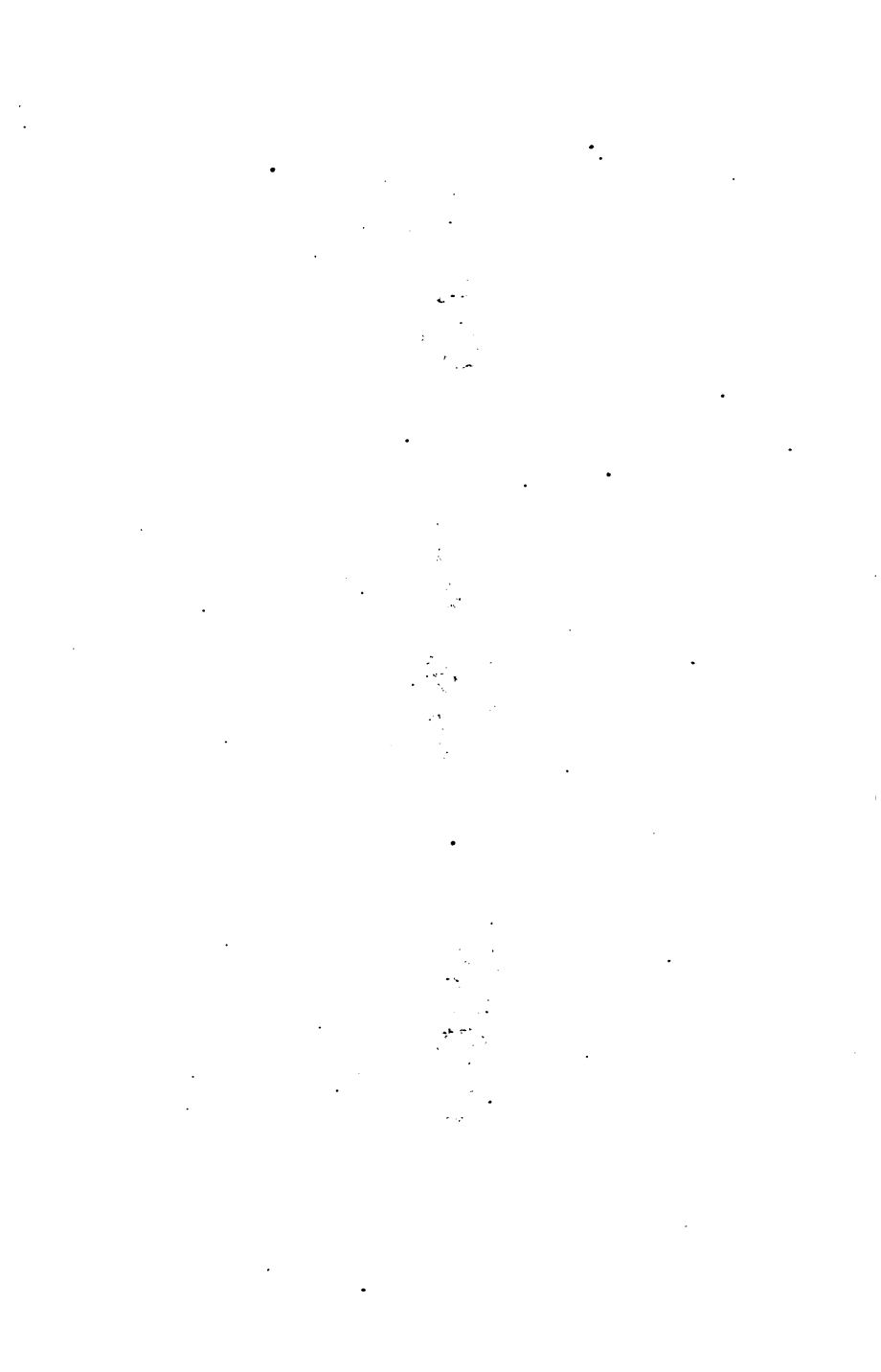
PLATE I.

Vespa Crabro. ♂ ♀ ♂. page 35.

* ♀. Diagram of the face with the surrounding rim.

* ♂. The same, with the mandibles thrown more forward.





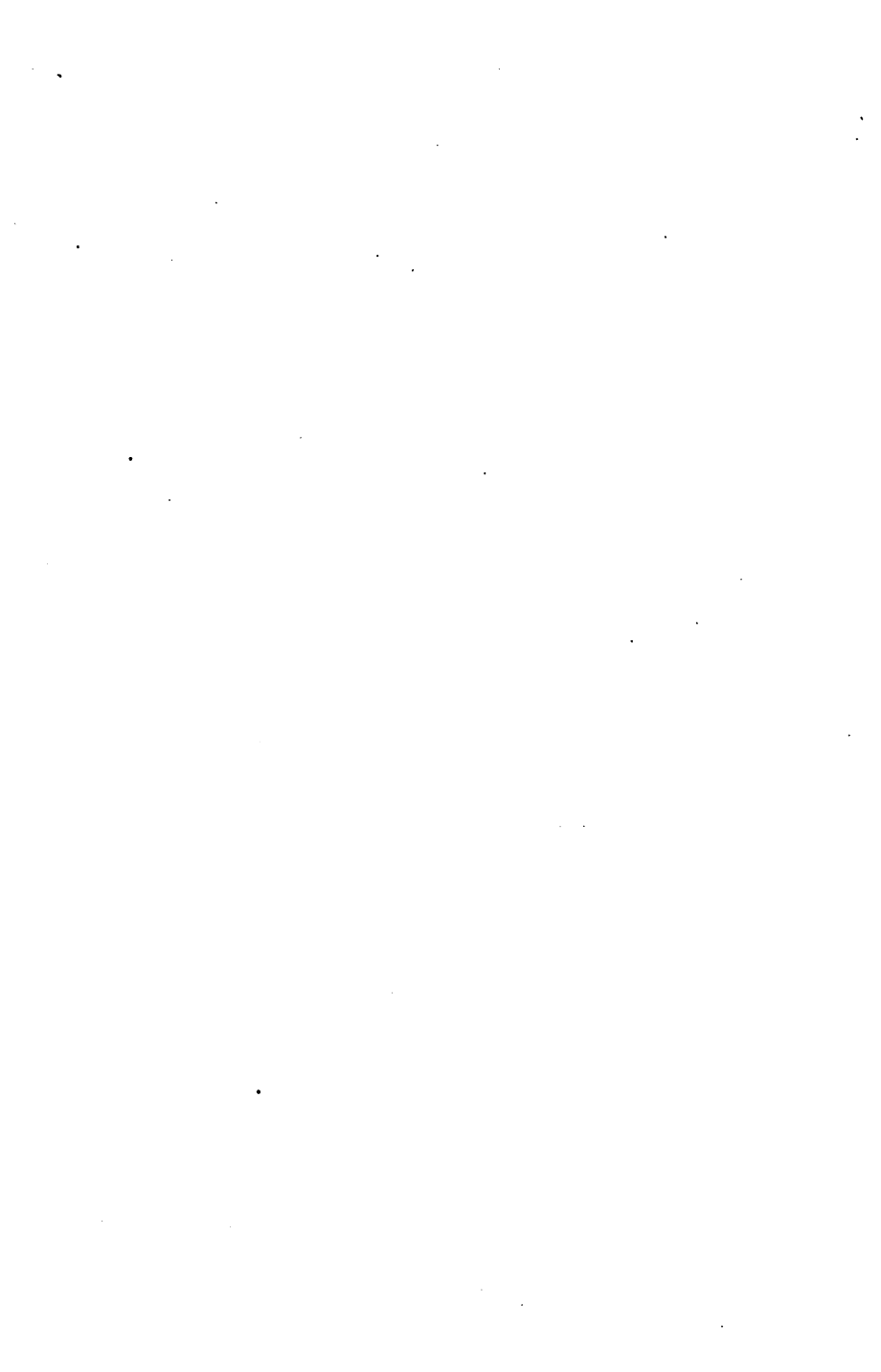


PLATE II.

FIG. 1. *Vespa britannica* or *norvegica*. ♂ ♀ ♂. page 39.

* ♂. Diagram of the face.

FIG. 2. *Vespa sylvestris*, *holsatica* or *campanaria*. ♀ ♀ ♂.
page 41.

* ♂. Diagram of the face.

The crosses denote the actual size of the specimens from
which the drawings were made.

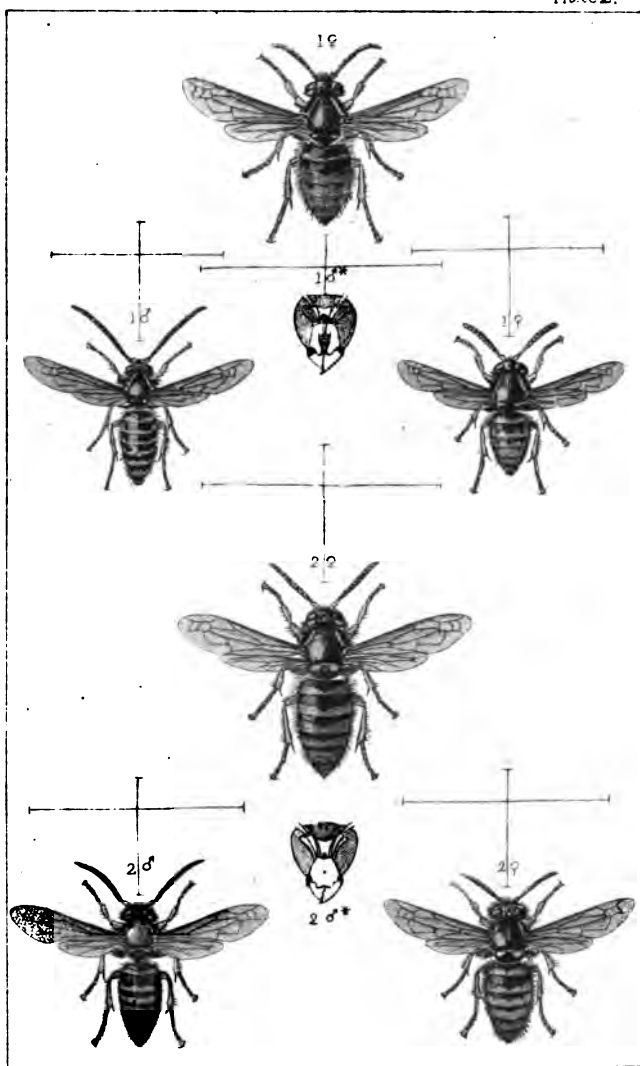






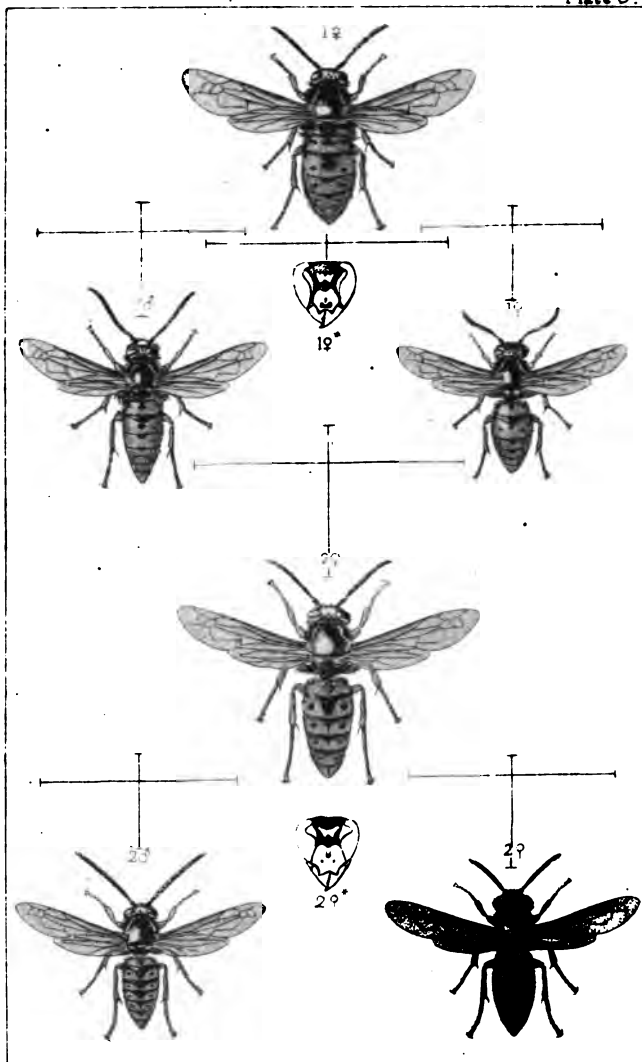
PLATE III.

FIG. 1. *Vespa arborea* or *borealis*. ♂ ♀ ♂. page 42.

* ♀. Diagram of the face.

FIG. 2. *Vespa germanica*. ♂ ♀ ♂. page 43.

* ♂. Diagram of the face.





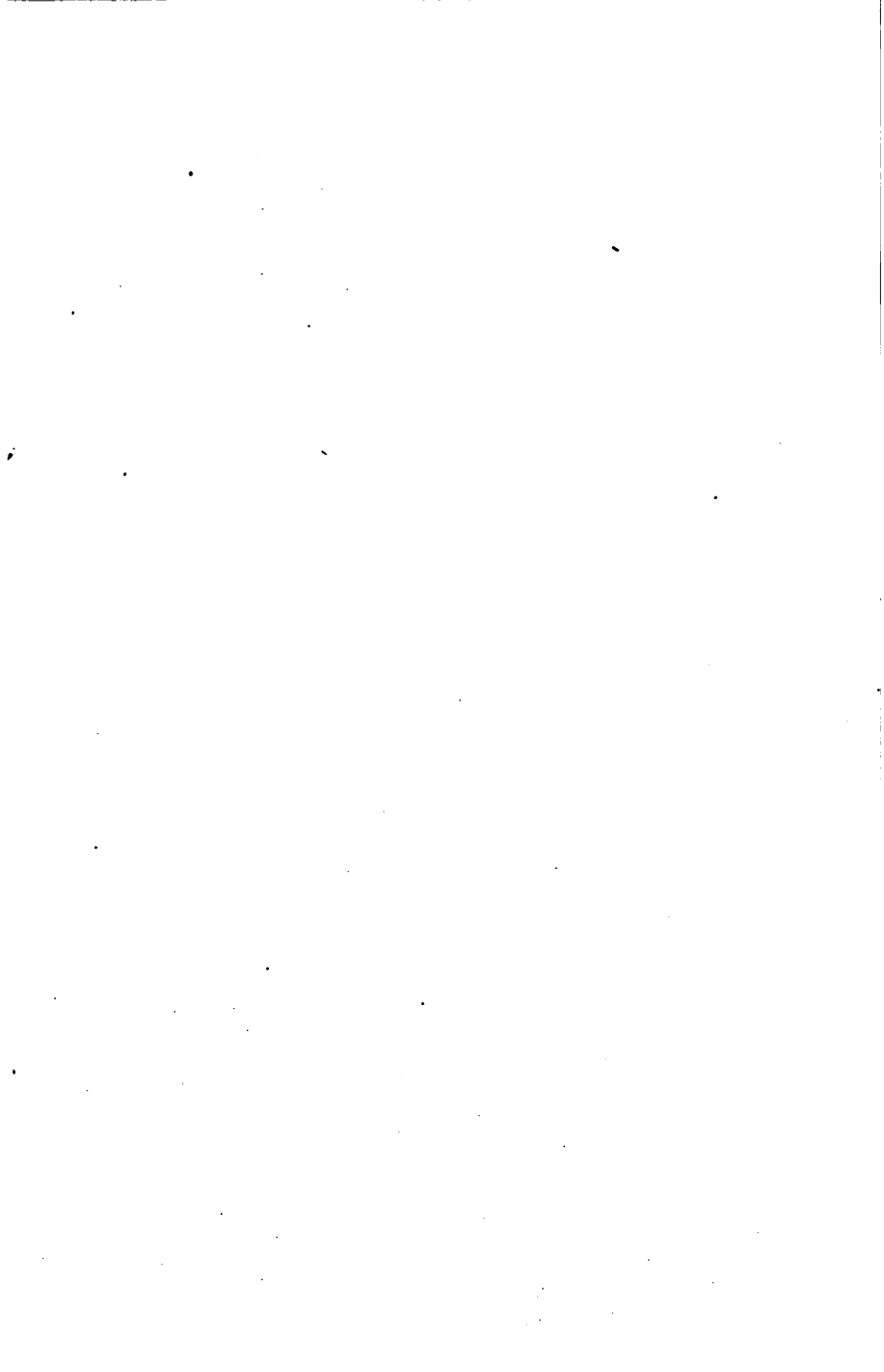


PLATE IV.

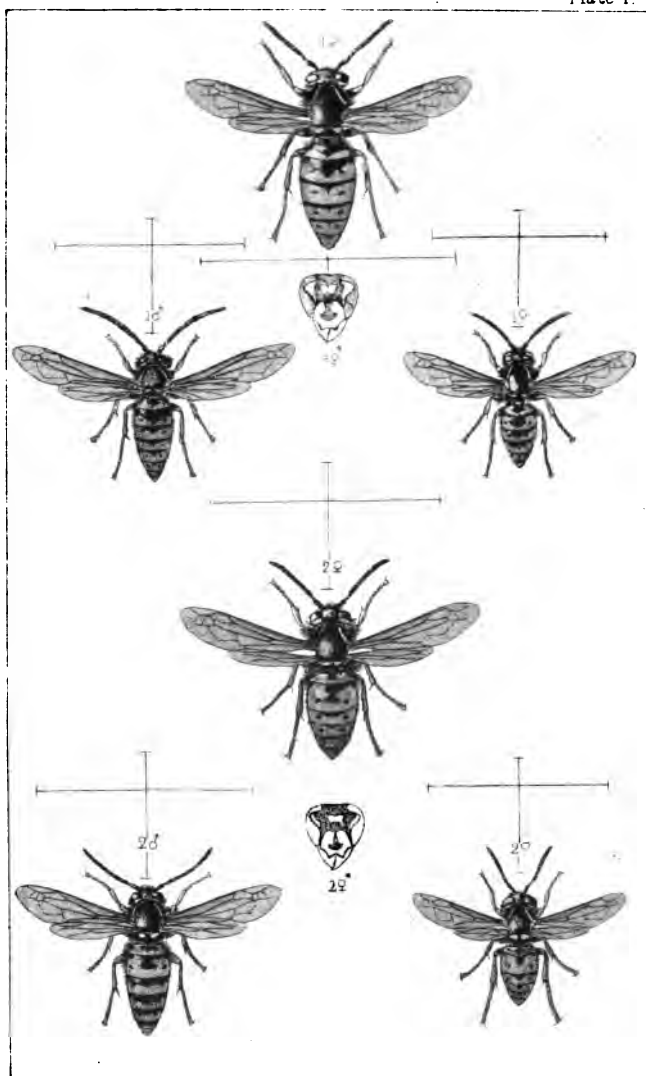
FIG. 1. *Vespa vulgaris*. ♂ ♀ ♂. page 45.

* ♀. Diagram of the face.

FIG. 2. *Vespa rufa*. ♂ ♀ ♂. page 47.

* ♀. Diagram of the face.

Plate 4.



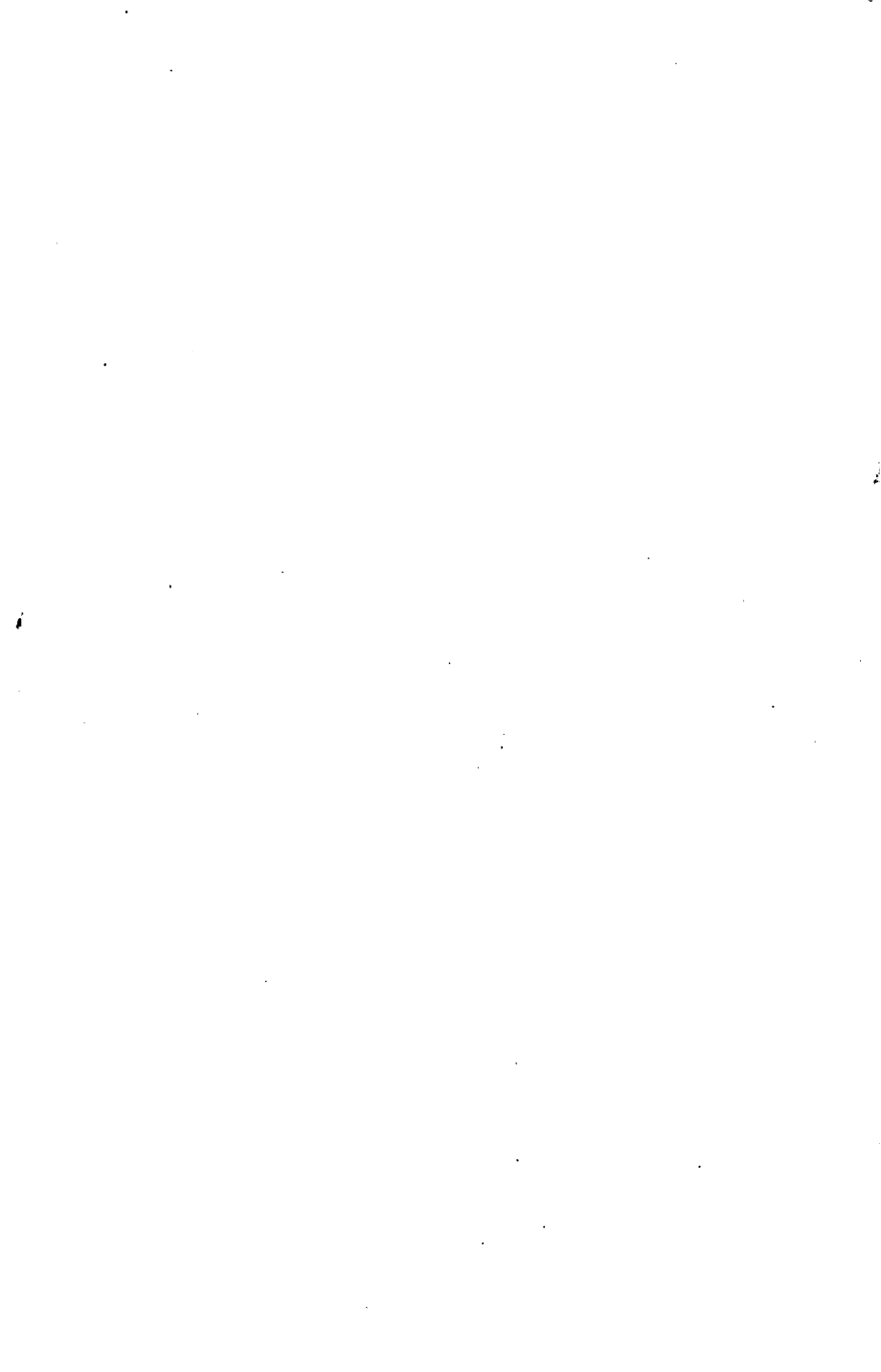


PLATE V.

FIG. 1. Embryo nest of tree-wasp at a very early stage, with no more than four rudimentary cells, and only a single hood springing from a triangular strap of paper. Natural size. p. 187.

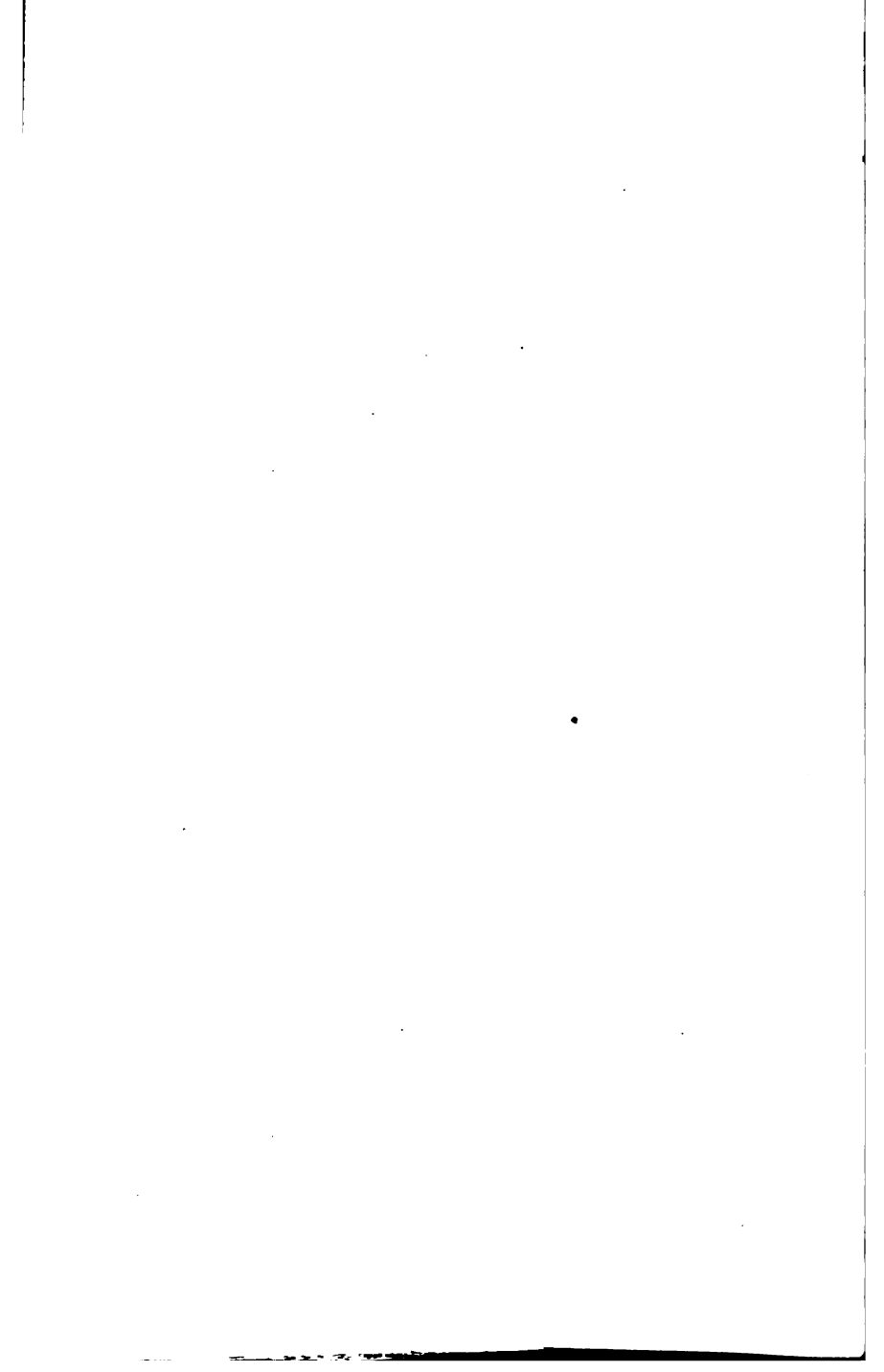
FIG. 2. Embryo nest of *V. britannica* (?) at a somewhat later period, attached to a shred of matting; the bottom of the nest not yet closed in. Natural size. p. 188.

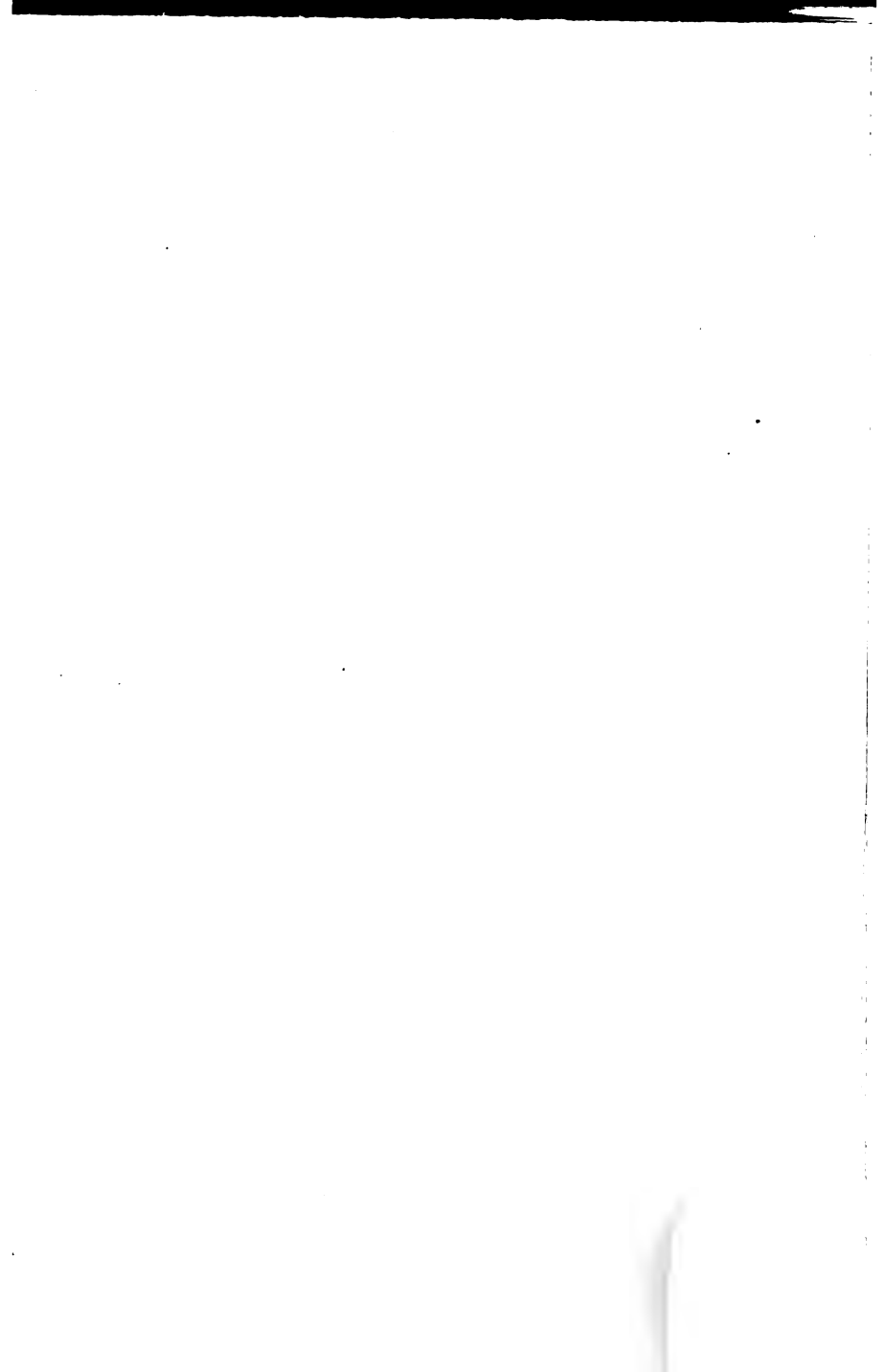
Fig 1

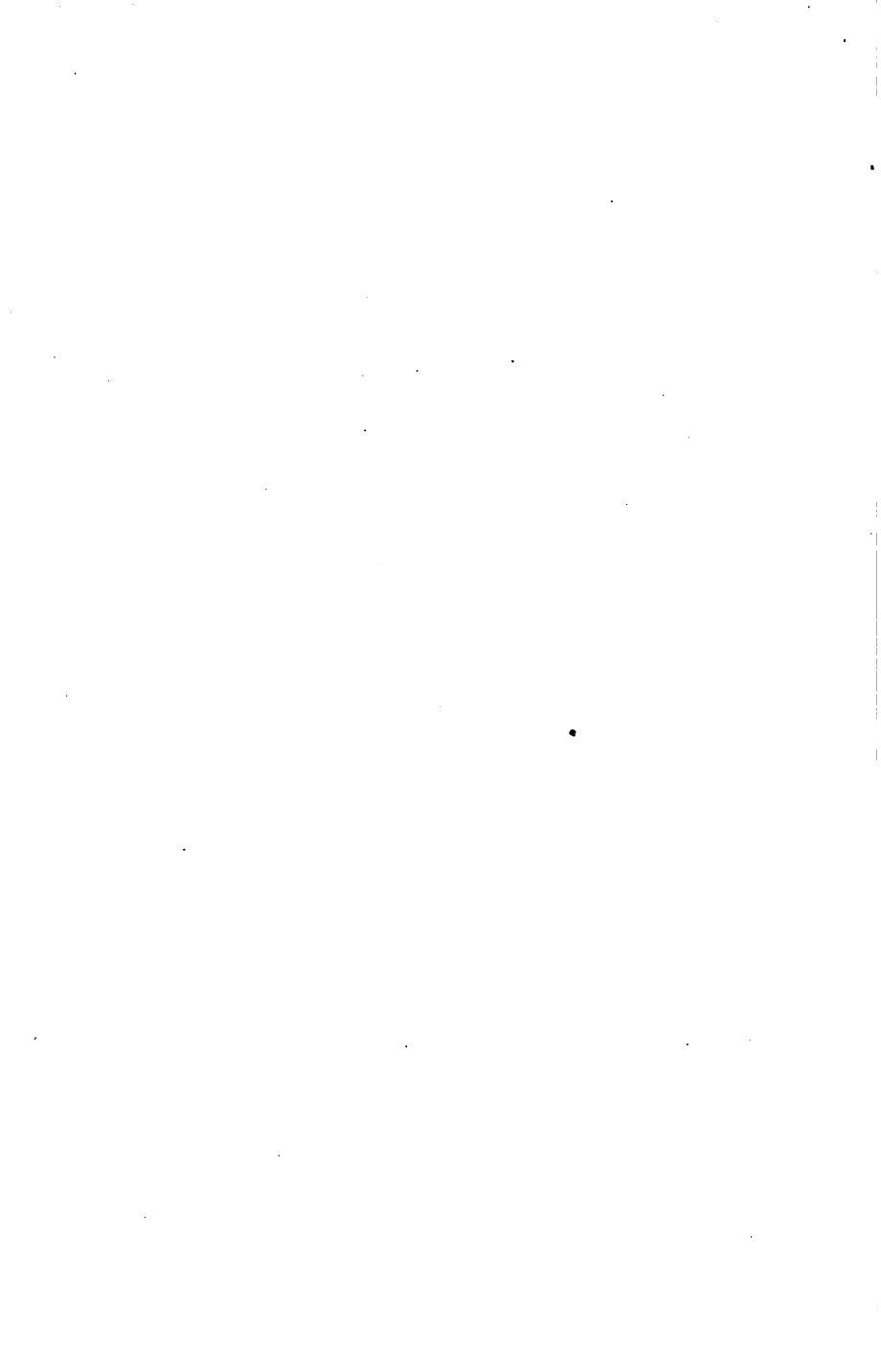


Fig 2









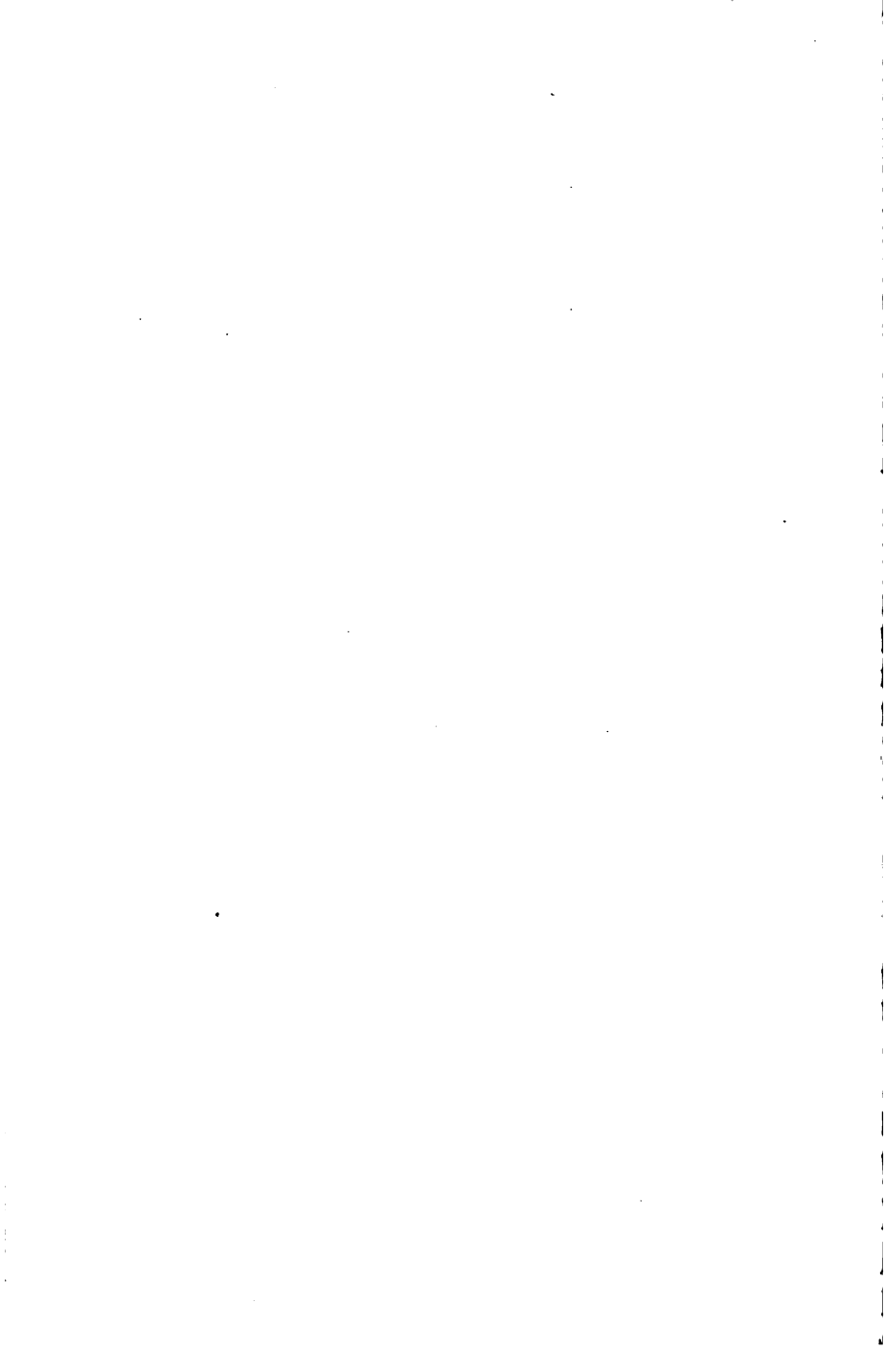
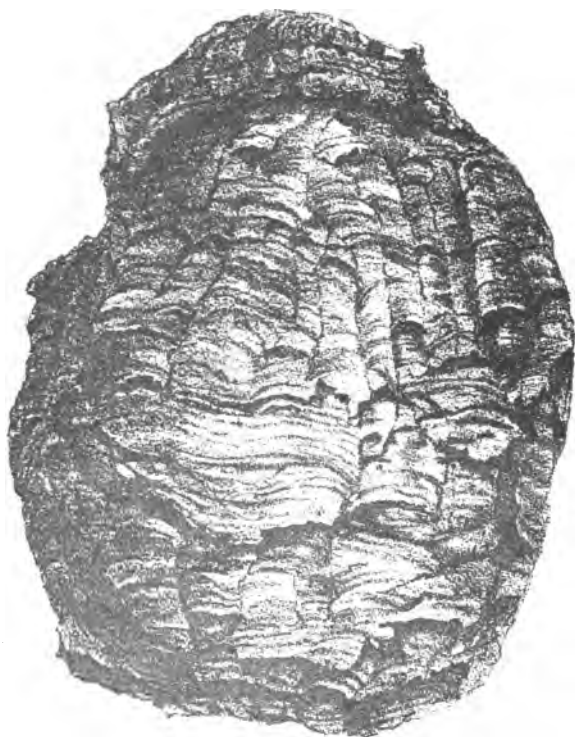




PLATE VII.

Large ovoid nest of *V. Crabro*, from a cottage roof. The top shows the place where it was attached to the rafters; the bottom has been partially broken away; the longitudinal tunnels and the horizontal lines of structure are clearly displayed. The drawing is rather more than one-fifth of the natural diameter. p. 210.

Plate 7.



M.O. del.

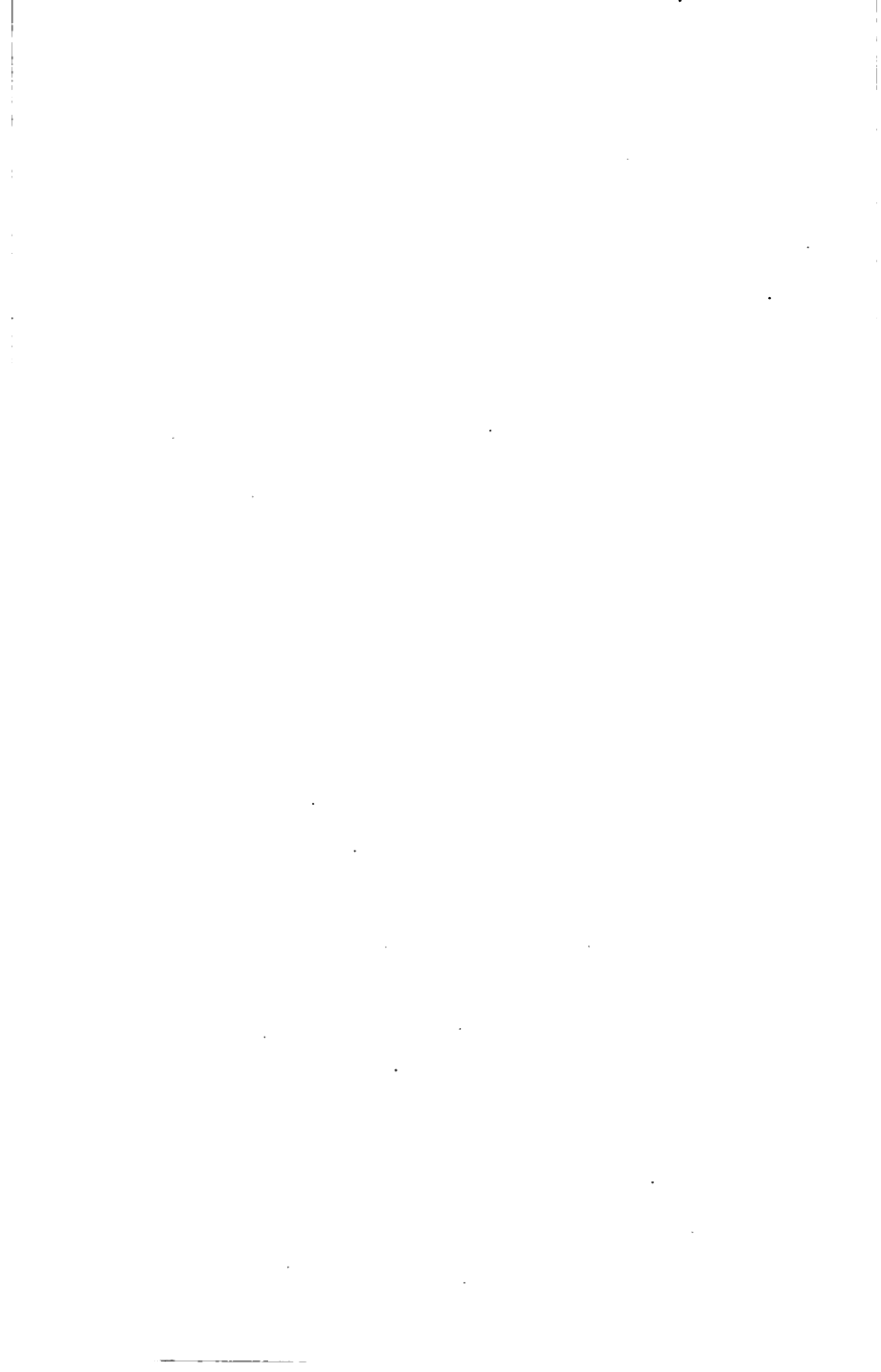
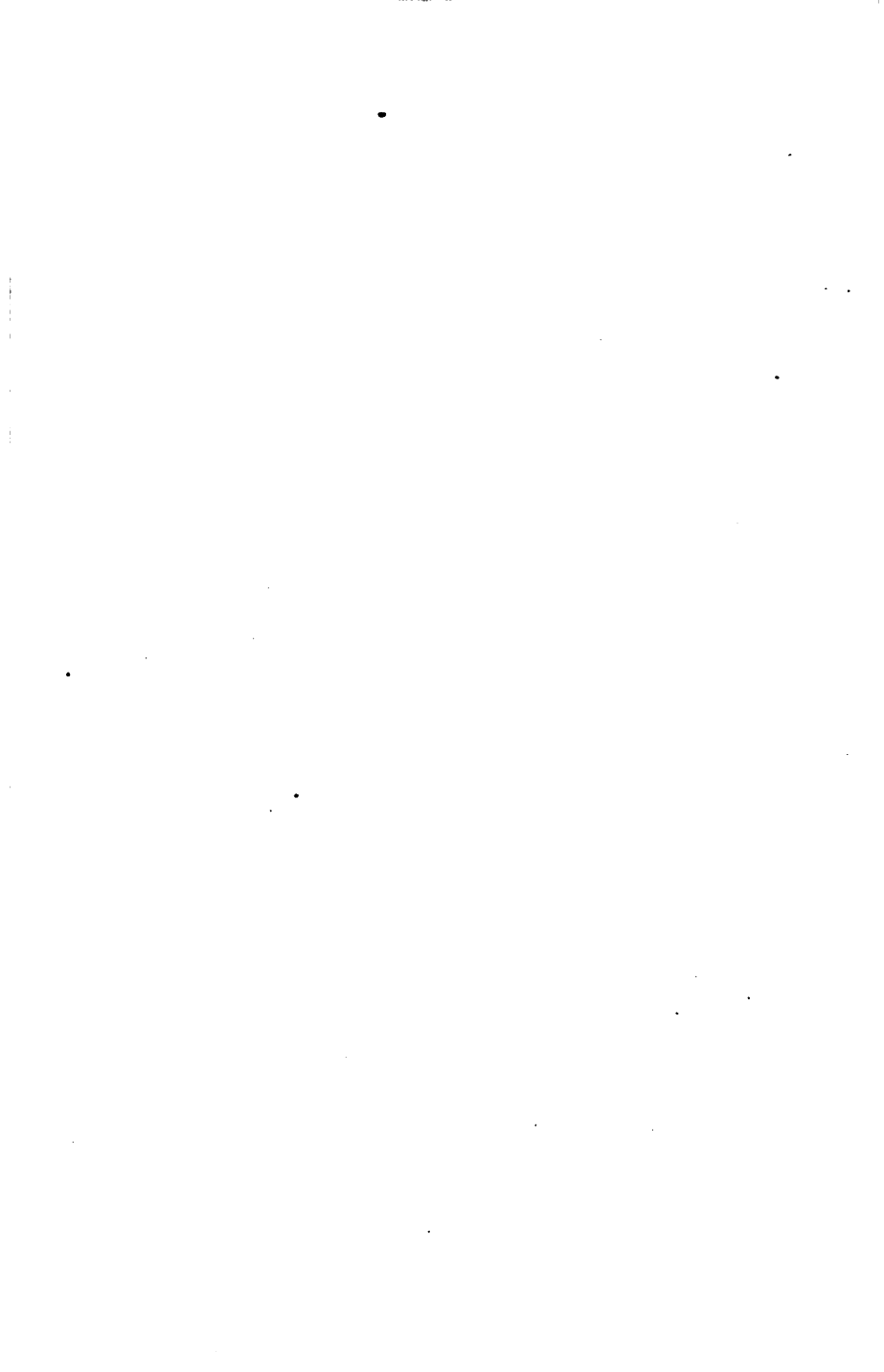


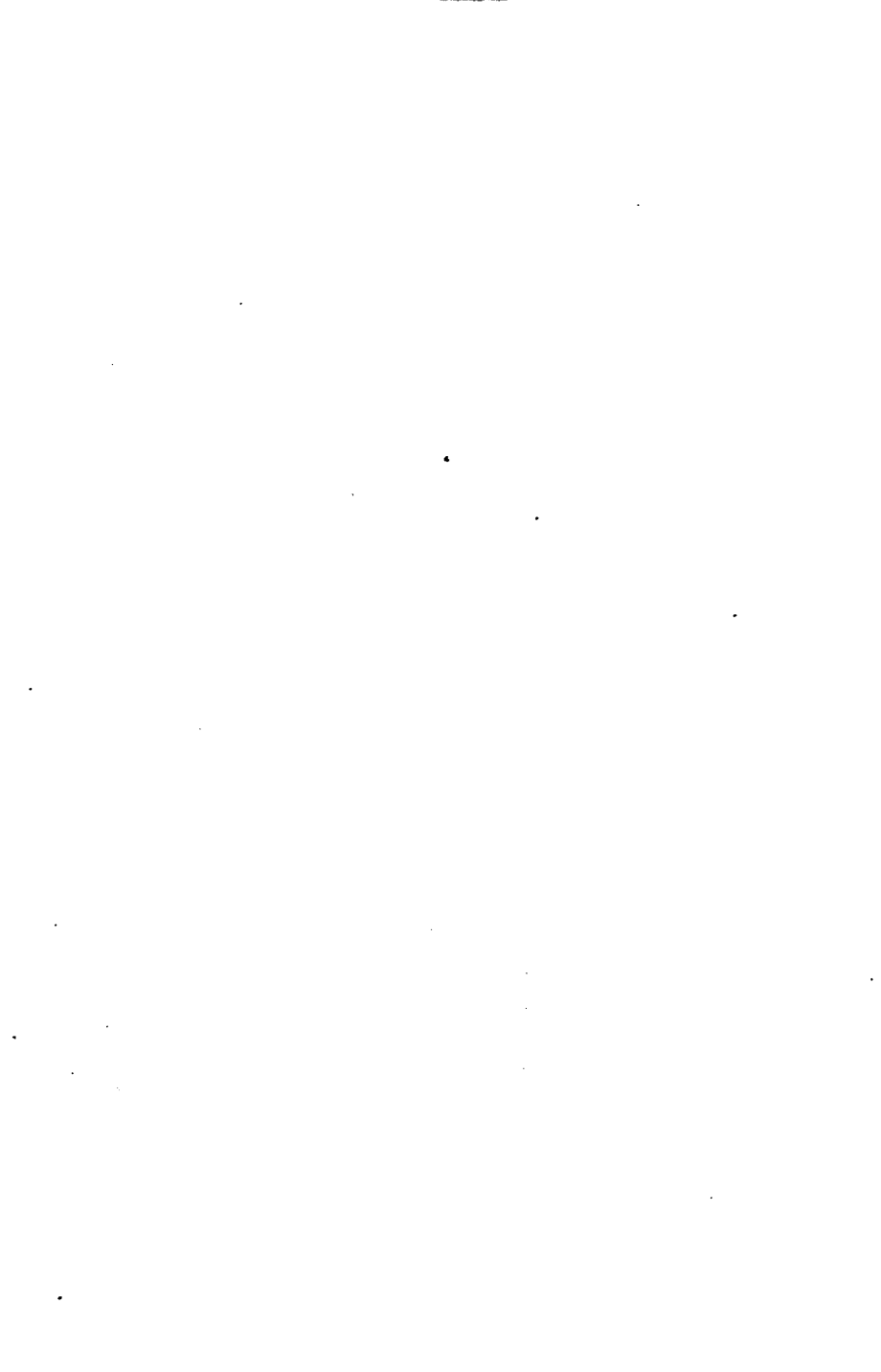


PLATE VIII.

Spherical nest of *V. vulgaris*, dug out of the ground. The varied arrangement and hue of the shelly patches of which the case is composed contrast with the structure and colour of the hornet's nest. Five-eighths of the natural diameter. p. 212.







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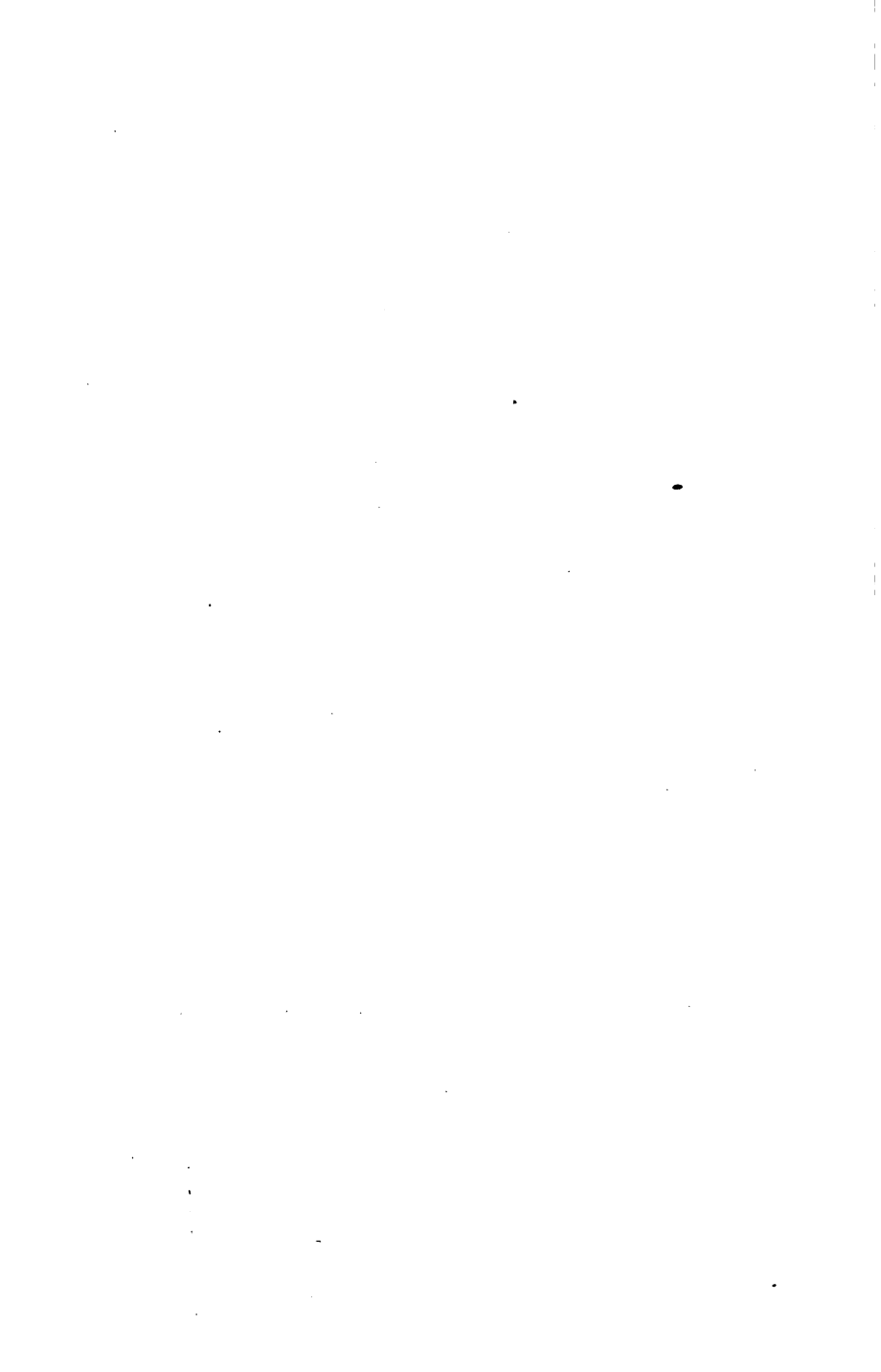
PLATE IX.

Flattened spherical nest of *V. germanica*, from a cottage roof, to which it was attached by a single strap of paper. The shelly patches are flatter than those made by *V. vulgaris*, and the whole nest is of a monotonous dull grey colour. Half the natural diameter. p. 213.



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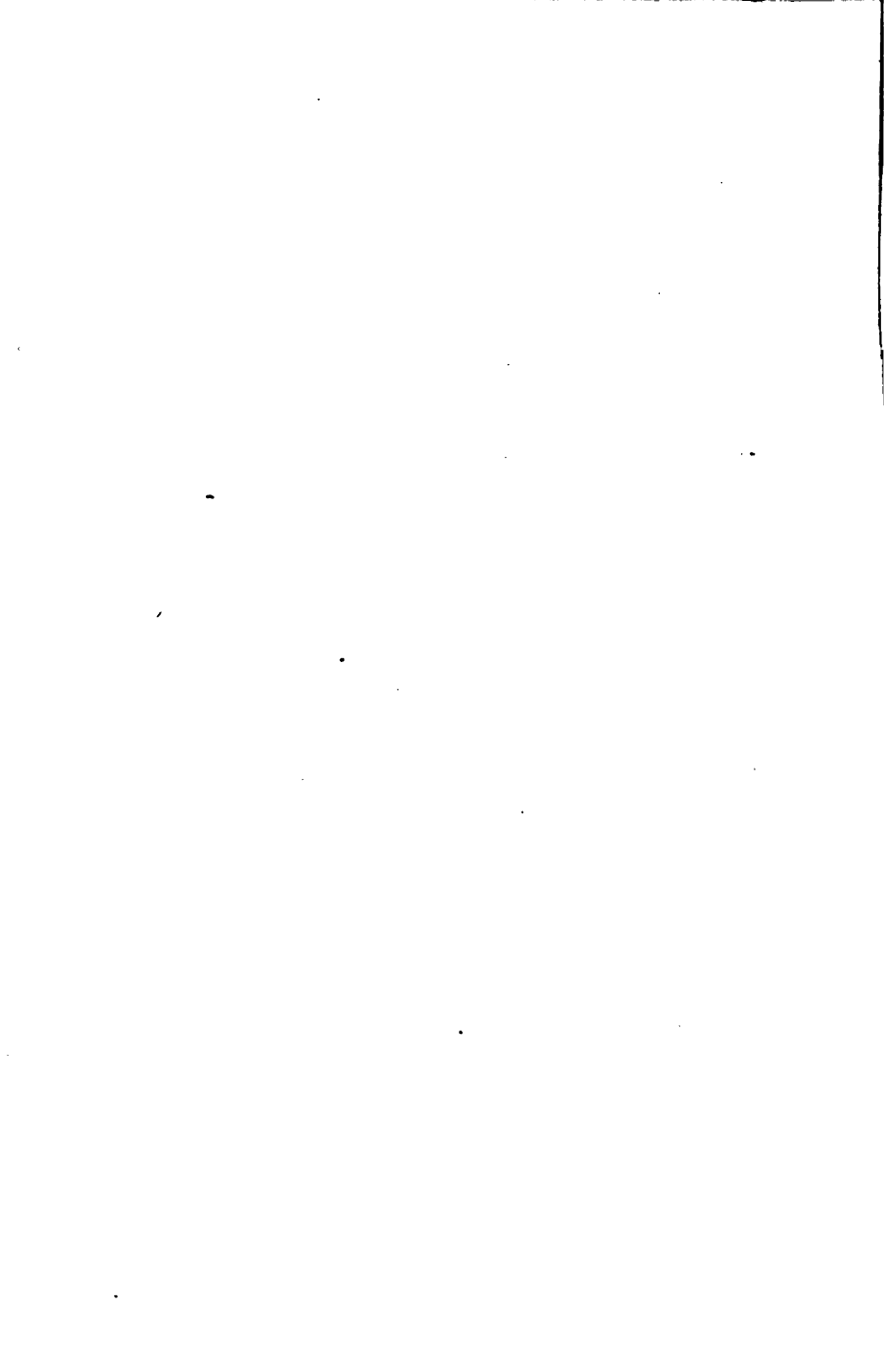
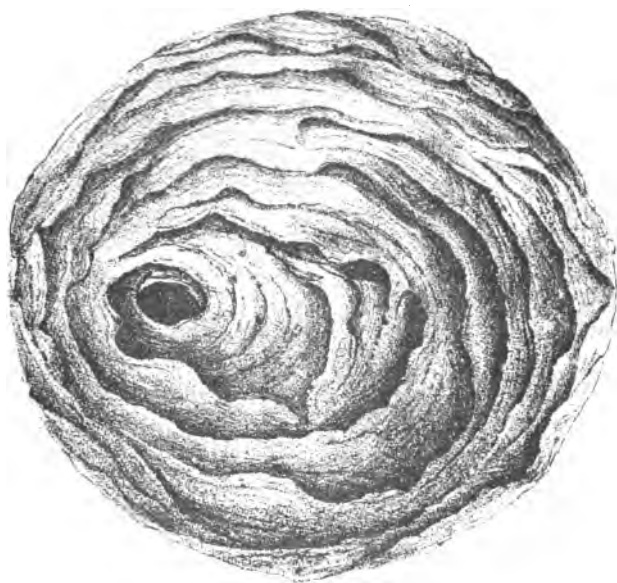


PLATE X.

Nest of *V. rufa*, turned upside down so as to display the entrance. The edges of the frills with which the surface is covered are plainly shown. The nest is spherical and of the same size as the drawing. p. 214.

PLATE XI (*facing the Title*).

Oval nest of *V. britannica*, from a pear-tree. The thickness of the case, the free irregular way in which the sheets of paper overlap and are connected to each other, and the loose ragged edges are characteristic of the architecture of this species. The entrance hole is represented, as usual, rather to one side. The little horn or porch often found surrounding the entrance was absent in this specimen. About three-fourths of the natural diameter. p. 215.





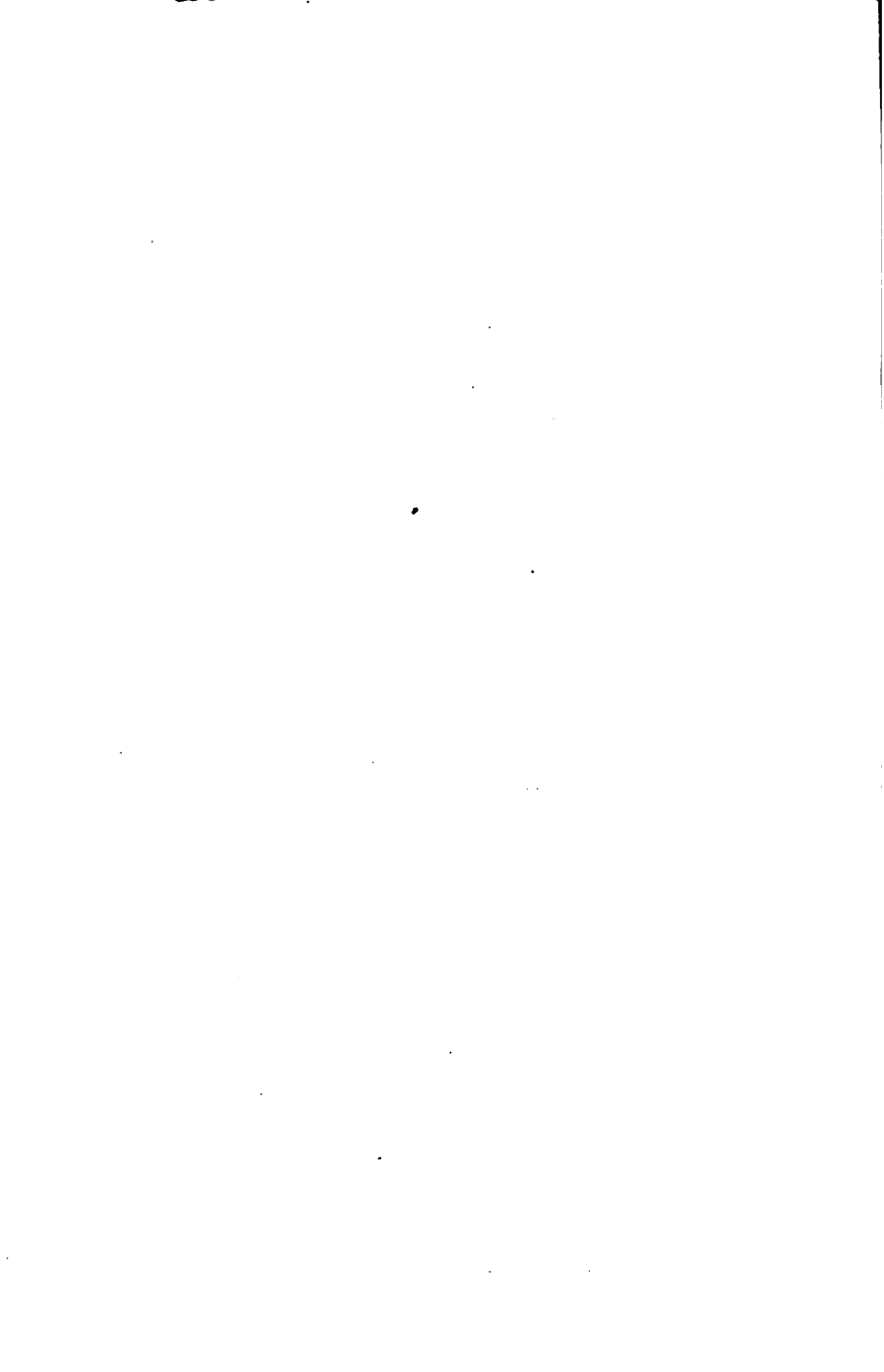
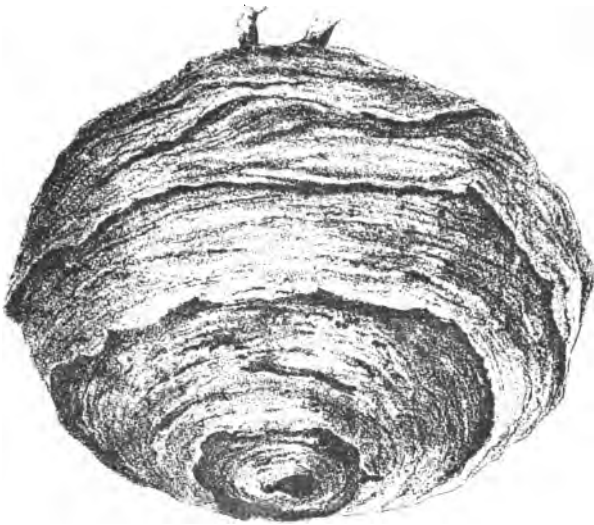
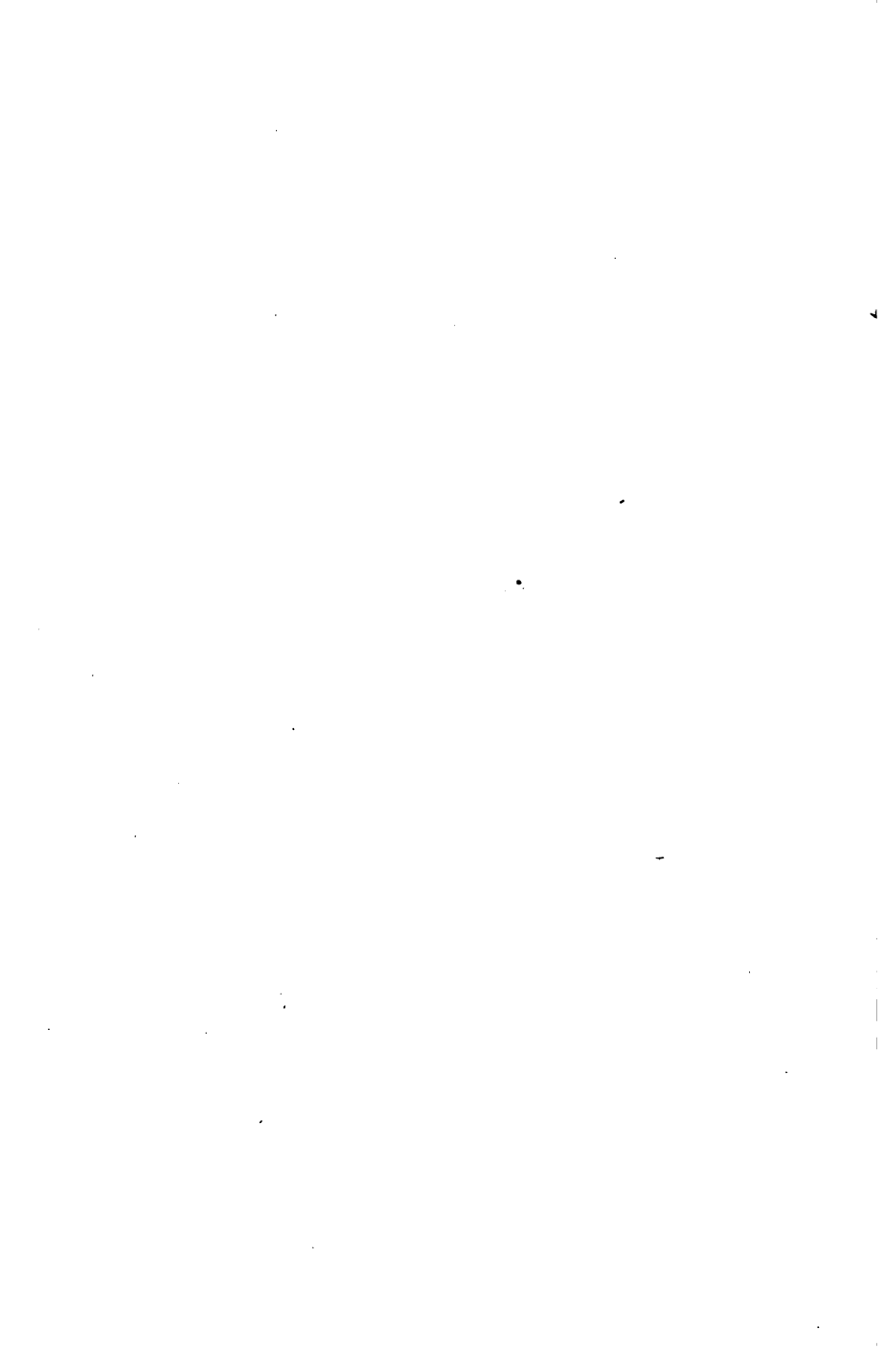


PLATE XII.

Spherical nest of *V. sylvestris*, of the most delicate and symmetrical construction, taken from a bee-house. This specimen contrasts strongly in both these particulars with the two preceding figures. Two-thirds of the natural diameter. p. 217.





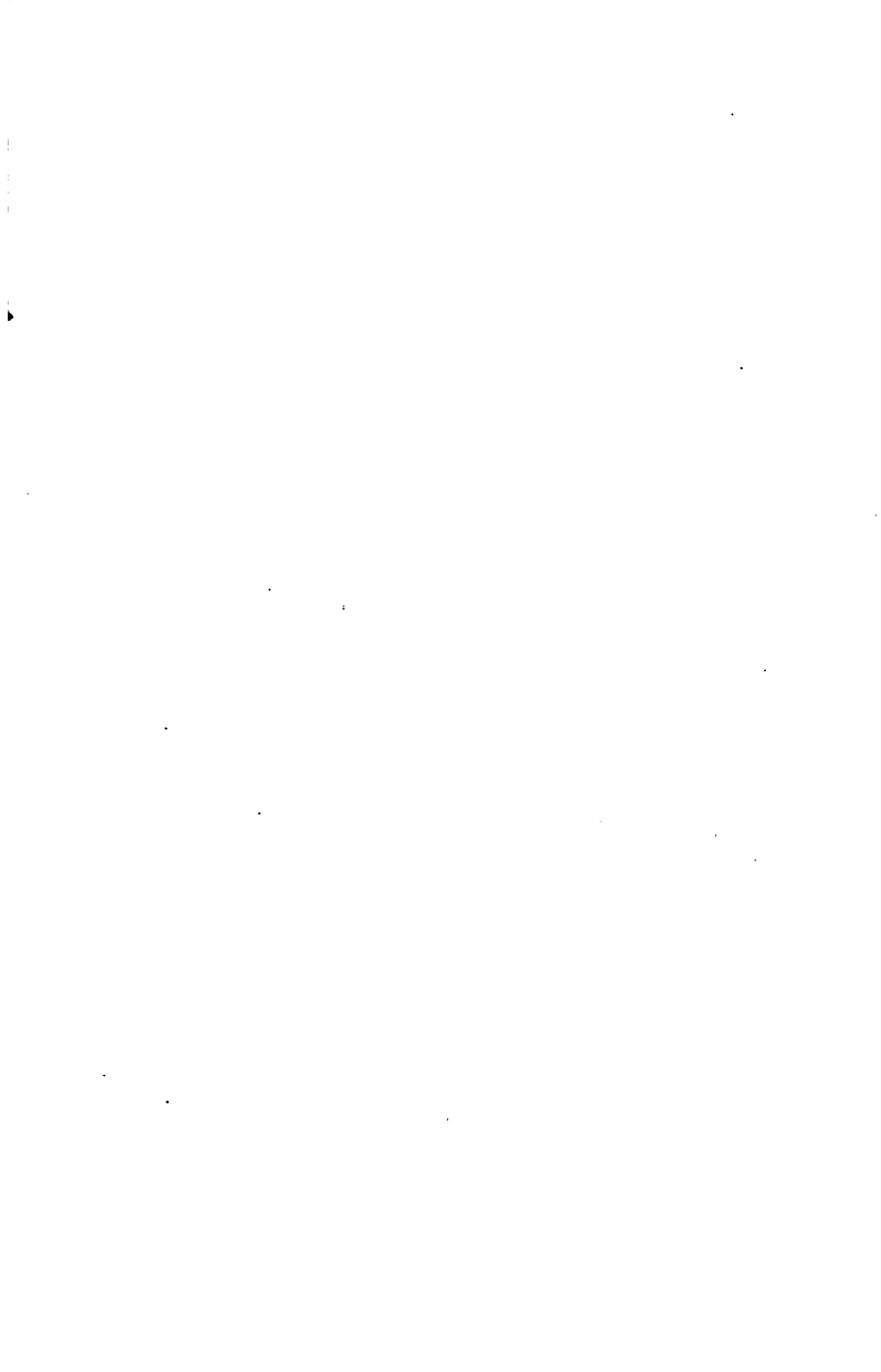


PLATE XIII.

Series of four nests made in succession by the same swarm of *V. britannica* in a hawthorn hedge. The position of the specimens has been adjusted to allow of their being all included in the same page. They are all drawn half the natural diameter.

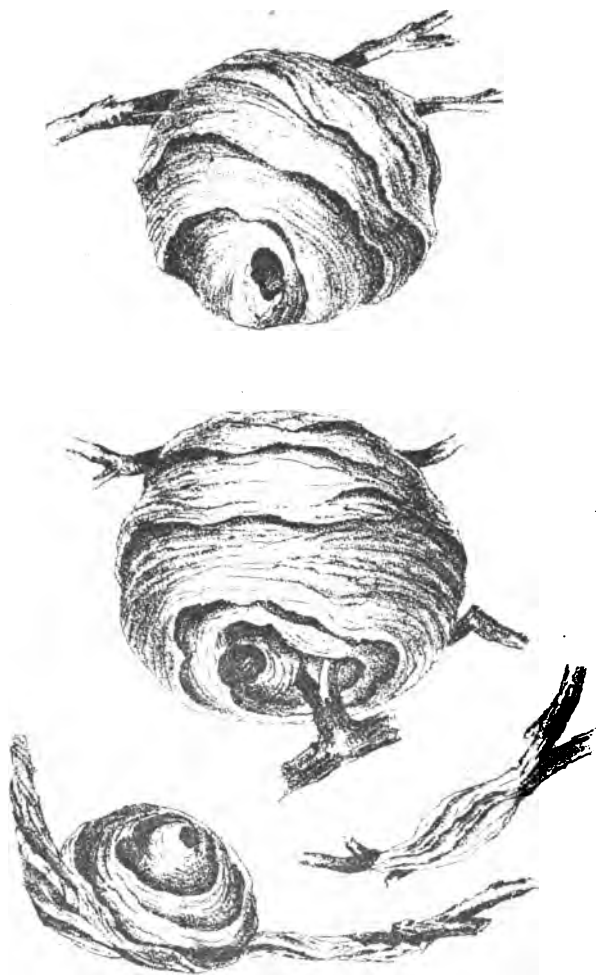
FIG. 1. First nest, taken July 2, 1864.

„ 2. Second „ „ „ 18, „

„ 3. Third „ „ „ 25, „

„ 4. Fourth „ „ Aug. 11, „

The last nest is little more than a few scraps of paper fastened to a twig. p. 259.



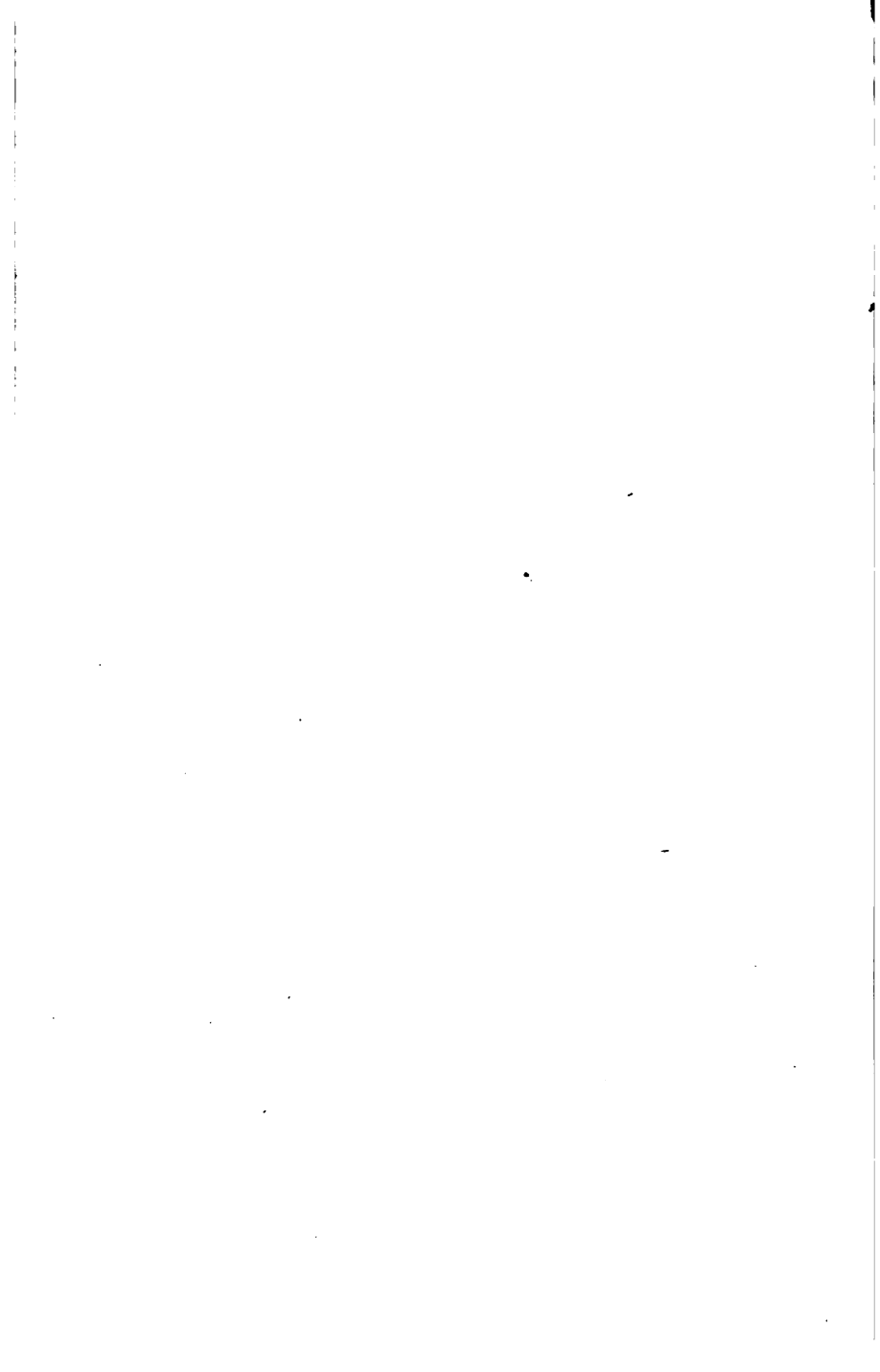




PLATE XIII.

Fig. 1. Four nests made in succession by the same swarm of *V. ruficornis* in a Hawthorn hedge. The position of the entrance has been adjusted to allow of their being all reached on the same page. They are all drawn half as nature is.

No. 1.	First nest, made July 2, 1894.
" 2.	Second " " " "
" 3.	Third " " " "
" 4.	Fourth " " " "

Fig. 2. A nest made by a different swarm of *V. ruficornis* in a Hawthorn hedge. The position of the entrance has been adjusted to allow of their being all reached on the same page. They are all drawn half as nature is.

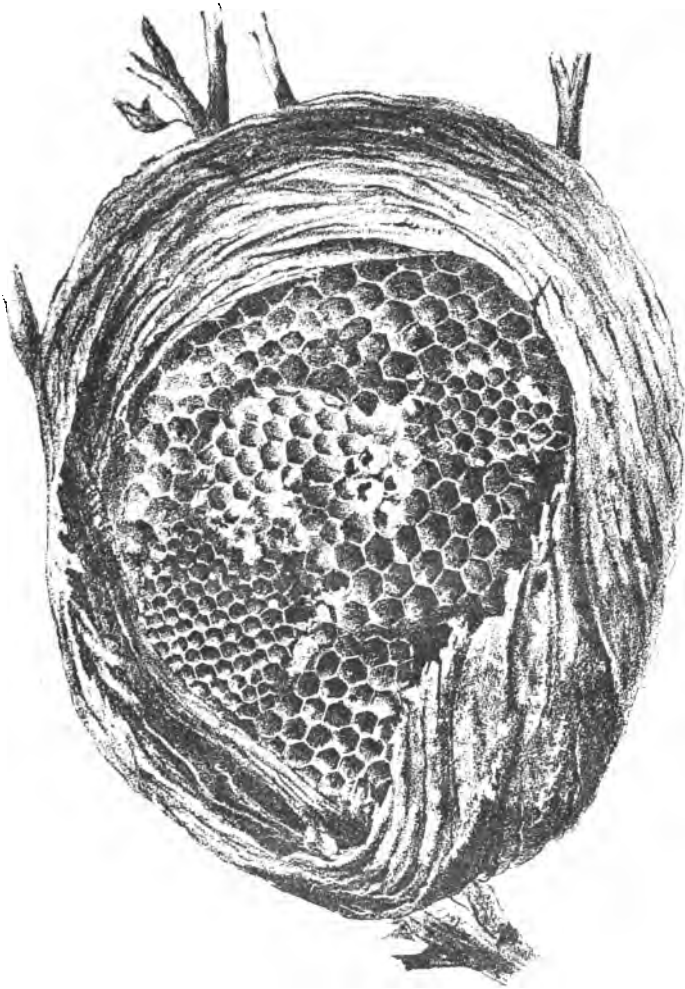


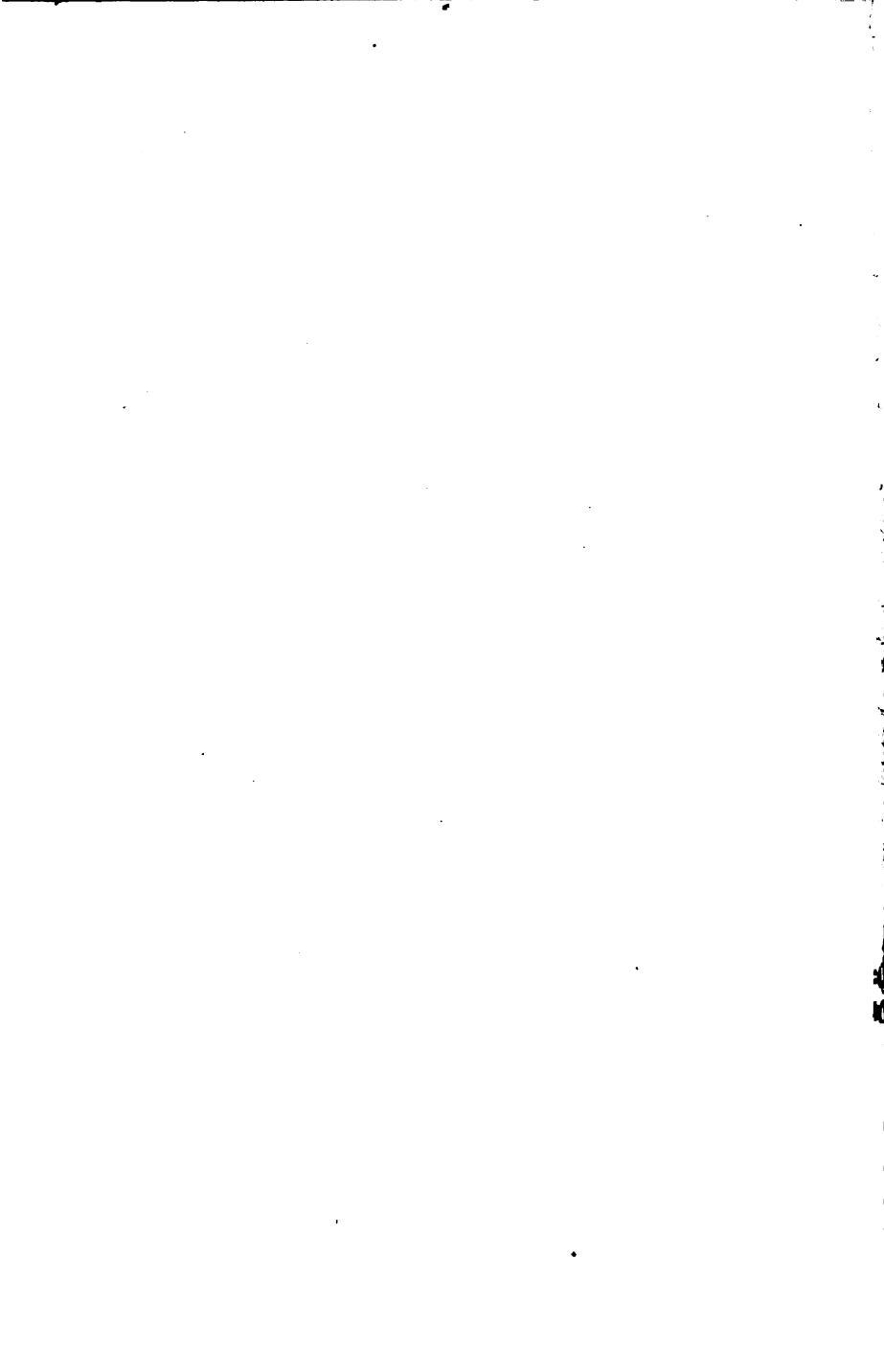




PLATE XIV.

Nest of *V. britannica* abandoned by the swarm after the loss of their queen. The case has been broken away to show the irregular mode of construction of the lower comb, which is built in separate patches of cells of different dimensions. Half the natural diameter. p. 266.





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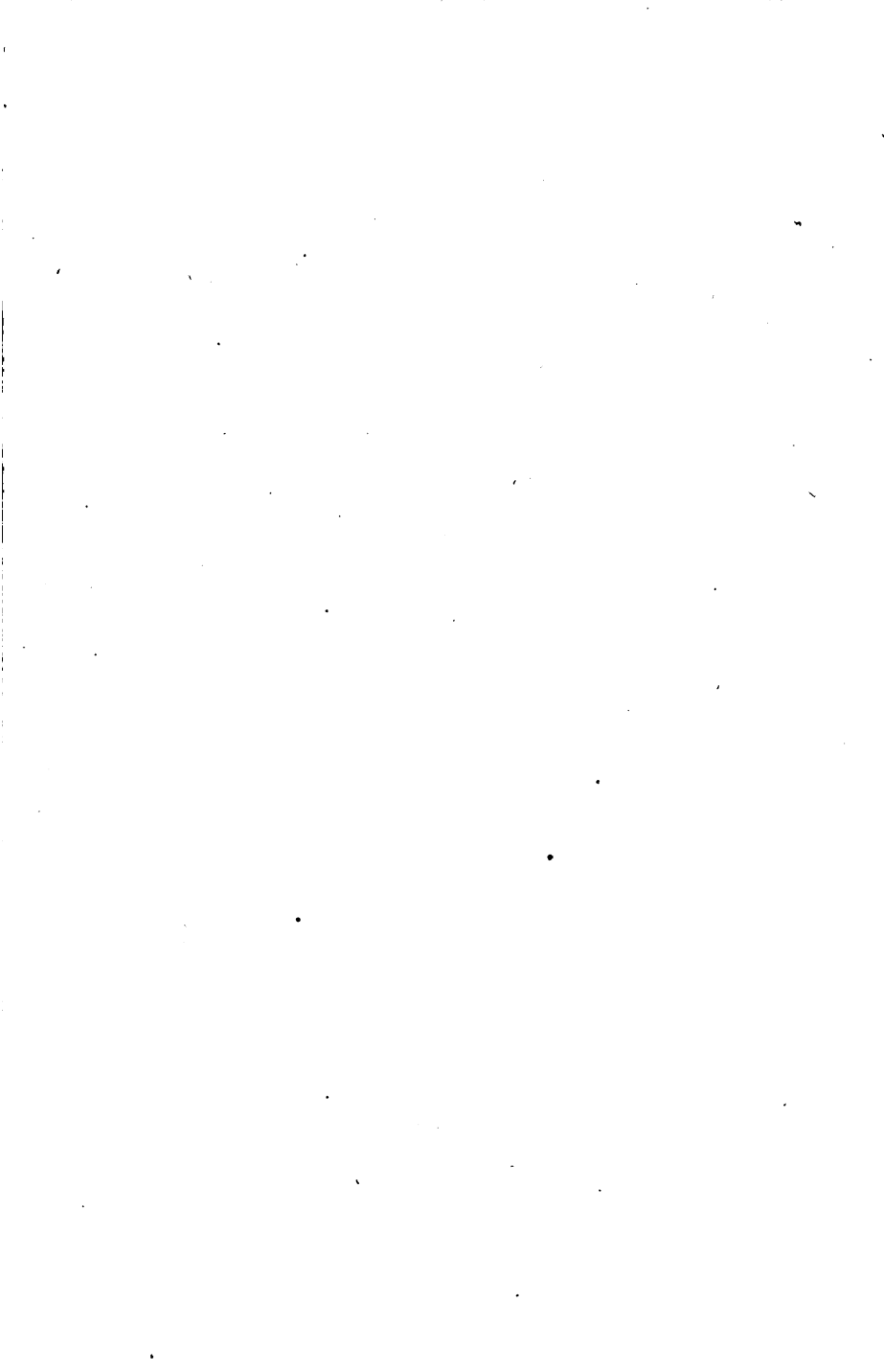
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